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PROCEEDINGS OF THE

Engineers' Society of Western Pennsylvania

VOLUME 25

ADDRESS OF JAMES K. LYONS

RETIRING PRESIDENT

The year just closed was not one of industrial activity and as a consequence not many large engineering projects were put under way. However, for such occasional periods of inactivity, the engineer ought to be truly thankful, or, at any rate, duly appreciative, although we rarely find him in either mood. The relief from the high tension work experienced during times of great industrial activity cannot help but be of positive benefit. Then the engineer must be a doer of work, with the time limit reduced to a minimum and must necessarily work along established lines. In the great rush and stress of business there is little or no time for thought of improvements in either design or method of work. But in a period of reaction, such as the past 12 or 18 months, the engineer has his golden opportunity to create, improve and develop along the lines of his work. In this connection it may be remarked that a thorough knowledge of the work and methods of those great men, who have gone before, as well as those of our own day, is indispensible to individual progress. This cannot be had without painstaking research and careful study. So we shall doubtless see, in our own world of engineering, the results of much new thought during the period of prosperity, which seems about to be opening before us. For, after all, a few months of industrial inactivity cannot halt the progress of the human race, although it may for a time obscure it.

Delivered at the Annual Meeting, January 19, 1909, and published in the February 1909, Proceedings.

It might not be amiss to glance back over the past 12 months and sum up briefly what has been proposed, inaugurated or accomplished and of interest from an engineering standpoint in our own vicinity.

In the way of large bridges, the new bridge of the Pittsburgh & Lake Erie Railroad over the Ohio River at Beaver was contracted for with Pittsburgh firms for the substructure and superstructure. The present channel span of this bridge was erected during the winter of 1889-1890, so that its usefulness will cover a period of about 20 years. During the past ten years the average increase in the live load for railroad bridges has been between 2½ and 3 per cent per year. It is probable the live loads will continue to increase for some years, as the economy of operating with increased loads is a demonstrated fact, and as a result the railroads are increasing the weight of a minimum car load.

In mechanical engineering, a twin-tandem compound direct-connected reversing mill engine of 20 000 horsepower was built by a Pittsburgh firm, and put in operation at one of the large steel works. This Society was accorded two opportunities for examining this machine, one at the machine shop and the other in actual operation driving the mill, so further comment is unnecessary.

A new Portland Cement Plant was placed in operation near Pittsburgh, with a daily capacity of 4500 barrels. This cement is manufactured from the slag of blast furnaces and limestone, and is, in fact, a true Portland cement. The electricity for driving the machinery in the cement plant is generated by gas engines, driven by the waste gases from the blast furnaces.

During the past year the filtration plant for Pittsburgh was completed and placed in operation, and we feel that results will soon be observed in the reduced death rate from typhoid fever. Let us hope the day is not far distant when all the citizens of Greater Pittsburgh will be supplied with filtered water.

During the past year the United States Geological Survey has established a Testing Station at the Arsenal grounds in

this city. This station at present is giving attention to coal. While this station has been in operation but a short time, still very effective work has been done, and we are justified in expecting much good to be accomplished along lines of improved methods in mining and in the safeguarding of human life in the mines. The number of lives lost per thousand of mine employees in this country is too high when measured by the loss of other countries.

In addition to these five items of interest in the Greater Pittsburgh District, I have in mind the new traction line bridge over the Mississippi River at St. Louis. This bridge will be located between the Eads' and Merchants' bridges, and will give the Illinois Traction Lines entrance into the City of St. Louis.

The contract for the new Terminal Station of the Chicago & Northwestern Railway of Chicago, Ill., was let during the latter part of the year. It is difficult to determine whether this new station will practically eliminate all hope for one large Terminal Station in Chicago, which would afford accommodations for all the railroads entering into the city.

In Electrical Engineering, the transmission of currents of electricity at 110 000 volts was accomplished. The increase being from 70 000 volts, the highest in use until the increase occurred.

In Mechanical Engineering, the Internal Combustion Engine, shows a thermal efficiency as high as 43 per cent during tests. It is certainly very probable the manufacturers will be offering in the near future, engines which will develop a thermal efficiency between 30 and 40 per cent.

The engineer has made an excellent record with the great transportation interests of this coutry, in the location and construction of the railroads—the great arteries of commerce. In the construction of bridges, in the designing of the motive power and other equipment, the work of the engineer has been eminently satisfactory. However, there are numerous questions at issue between the railroads and the people in reference to the freight and passenger rates, which have resulted in laws

being passed in many of the States regulating the rates by the legislatures.

To digress for a few moments: The moving of freight is the performance of work, the amount of the same should be a quantity readily determined under present conditions, with a reasonable degree of approximation. May we not expect the rate problem to be settled on a basis somewhat as follows? A uniform classification for the entire country, with a total of not more than ten classes, the fewer the better,, with a complete list of the commodities under each class. Fix a ton mile rate for the various classes of freight, plus a fixed terminal charge to cover what are termed "switching rates," at the point of shipment and for delivering at destination. On this basis the freight rate would be a function of the number of miles through which the material is moved, times the ton rate per mile, plus the terminal charges. With a map upon which is marked the number of miles between the various trade centers or cities of the country, a uniform classification sheet and a rate sheet giving the ton mile rate for the various classes of freight and the terminal charges, it would be a very easy matter for any person to determine the rate. Many of the freight rates have been and are determined without any regard to the work basis, and consequently have proved very unsatisfactory to the people at large.

Cannot the engineers do something to solve this greatest problem so far as the national welfare is concerned? The problem cannot be solved quickly, but will require gradual modifications, all tending toward a common result that will produce an equality in rates, which will be satisfactory to the people. In the making of freight rates in the past, the railroads determined the points which should be manufacturing centers and thus assumed charge of the manufacturers for the entire country. Many times the manipulations were for selfish motives, the ultimate national welfare being entirely eliminated. If the manufacturing interests had been more uniformly distributed over the country, it is very probable the immense freight blockades that have been experienced in the

past would have been avoided at times of intense commercial activity.

The rates question has been referred to, because it is the source of contention and until it is settled to the entire satisfaction of the people, we cannot hope for a period of good feeling and attention given to the national development under conditions that will be fair to all alike and with favors to none.

At one time there was talk about Government ownership of the railroads, but this is forgotten and the people seem to have discovered a simpler and more effective method of obtaining the desired result, viz., in rate regulation and control. If this control should take the form of commissions, let us hope that the engineers will be represented, because a great part of the work to be done is such, that only engineers are qualified to pass on it, by reason of their experience and training.

Material Distance		Miles	Rate per Ton Mile in Mills			
			Rail	Lake & Rail	Inland Water	Ocean
Chicago to Portland	Grain	1 138	3.1			
Chicago to New York	"	971	3.7			
Brandon to St. John, N. B.	"	2 038	3.7	2.2		
Spring Hill, N. S., to Montreal	Coal	738	2.5			
Chicago to Montreal	Grain	1 080		2.6		
Chicago to Montreal	"	827		2.1		
Chicago to Montreal	"	1 175			2.3	
Duluth to Cleveland	Iron Ore	875			0.9	
Chicago to New York	Grain	1 330			1.5	
Montreal to Antwerp	"	3 250				0.44
Duluth to Quebec	"	1 580			1.7	
Antwerp to Montreal	"	3 250				0.53
Montreal to Liverpool	"	2 900				0.46

COST OF FREIGHT MOVEMENT.

Year.	Cost Per Ton Mile—Mills.	Cost of Coal Per Ton.	Wood Per Cord.
1901	1.87	.....	.....
1902	2.22	$1.07	$1.25
1903	2.36	$1.35	$1.35

To return to our retrospect of 1908 we find that several national engineering societies have been formed, which are intended to serve the interests of specialists in a particular branch of engineering.

There are very few problems presented to the engineer which do not involve more than one branch of engineering in their solution. The engineering colleges have taken up the specializing of engineering courses and have an assortment of engineering degrees which will be conferred, depending upon the selection of the student. The speaker is not in sympathy with the specializing in engineering education, nor the forming of engineering societies devoted exclusively to special branches of the profession.

In the education of the engineer, the principles which govern the physical phenomena of the material world should be thoroughly mastered, also a good training in the English language and a fair knowledge of economics and business law. A fair knowledge of German and French is desirable and will be found a convenience, if our Esparanto friends do not supplant these languages. If a student desires to specialize it would seem to me he should do it as post-graduate work.

During the past year two meetings have been held at Washington, in response to calls of the President, to consider the conservation of our national resources.

Forest preservation is a question of importance to the Nation and its people, although the question of their preservation may be new in this country. We note a petition was presented to Queen Elizabeth in the year 1570, asking for the preservation of the forests of England, and asked that "the bloomaries" might be abolished on account of the quantity of wood consumed in them.

Japan began taking care of her forests two thousand years before America was discovered.

INLAND WATERWAYS COMMISSION.

In reference to the improvement of our inland waterways, the Mississippi Valley, which is drained by the Mississippi River and its tributaries, is the largest watershed in this country. This valley has an area sufficient to support four hundred million people, almost five times the present population of the United States. There can scarcely be any question raised regarding the desirability of improving the water-

ways of this great valley. Before a work of such magnitude is undertaken, very careful study should be made by engineers qualified for such work, and general plans developed and approved, before the commencement of actual construction. Maybe it would be desirable to make the plans public and invite criticism from the people, before taking up the actual work of construction. It is essential to carry on the work at a reasonable cost, and in order to do so, it is necessary to have continuous appropriations so that the construction may proceed without interruption.

The work on the Panama Canal during the past year has exceeded expectations, and in this connection, the general methods followed on this work, should give very satisfactory results, if followed in the improving of the Inland Waterways of this country.

In reference to coke produced in the ordinary oven, we have so eminent an authority as the late Sir William Siemens, saying, it has been satisfactorily proved to be inferior to that produced in closed or retort ovens. The coke produced in the ordinary oven has a bright silvery luster, which is much less pronounced on coke produced in closed or retort ovens, and it is to this difference we must look for an explanation against the use of coke with a darker hue and made in retort ovens. The use of retort or by-product ovens enables a considerable increase in the number of pounds of coke produced from a ton of coal.

Mr. Edmund W. Parker makes the following comments in reference to by-product coke ovens: "The economies consist not only in the higher yield of coal in coke, but in recovery of the valuable by-products of gas, tar and ammonia. In the course of time the wasteful beehive oven must give place to the more advanced and more economical recovery oven, and with this change will come a transfer, in large part, of the coking industry from the coal mining regions to points nearer the places of consumption, particularly of the coke and gas, and with this will also be made a long stride in the abatement of the smoke nuisance, from which so many of the interior Western cties are endeavoring to escape."

BY-PRODUCT COKE OVENS.

Ton of coal.	Coke—71 to 75 per cent.
Barrel—50 gallons.	Tar—8 to 10 gallons.
Gallon—10 lbs.	Ammonia Sulphate—20 lbs.
	Gas—6250 cu. ft.

In many of the manufacturing operations, the fuel represents from 25 to 50 per cent of the total cost of materials. Any reduction in the amount of fuel required, will help conserve the coal, reduce the cost of manufacture, and, as a result, will either give increased profits or lower selling price. The following will illustrate the opportunity offered, to save in the fuel used in one instance:

In burning lime about 7 414 000 B. t. u.'s are used for each ton of burned lime, while the theoretical heat requirements are about 3 775 000 B. t. u.'s, which indicates that the average lime kiln wastes about one-half the fuel put into it.

STEEL WORKS IN EUROPE.

	Steam Plant.	Gas Plant.
Coal used for boilers..................	5 300 tons	500 tons
Steel—production	21 400 tons	30 000 tons

Price of coal, $3.60 per ton delivered.

Internal combustion gas engines are being sold under a guarantee to develop an I. H. P. hour with 8000 B. t. u.'s and under test the I. H. P. hour was well under 7000 B. t. u.'s.

The great trouble at first with the use of gas in internal combustion engines was the cleaning of the gas, but the apparatus for doing this work has reached such a state of perfection that not more than 0.02 of a gram of dust or soiled matter remains per cubic meter of gas.

It was only in 1898 that the gas from the by-product coke ovens was first used in internal combustion engines, although some trouble was experienced at first, still all the troubles have been eliminated and now the results are just as dependable as they were with the steam engine and with very great saving in the amount of fuel required to produce the result.

The following notes may or may not tend to indicate that

we may expect decided advances to be made in the use of fuel in the near future for power and refining purposes.

In the year 1722, Reaumur, the distinguished French philosopher, proposed producing steel on a large scale by fusing cast or pig iron with wrought metal or scrap, but it was not until the year 1820 that steel melting was introduced into commerce by Huntsman, of Sheffield, England, using coke as a fuel in a furnace blown by an intense draft, such as is known as an air furnace today.

Murdoch, of Soho, erected his gas retort in the year 1792, then Lampadius published his investigations in 1801. Gas illumination was first practically used in the year 1815 in the City of London.

In the year 1817, a patent was granted to the Rev. Robert Stirling, of Scotland, foreshadowing the regenerative system. The specification was reprinted by the Iron and Steel Institute in 1886.

James Beaumont Neilson patented the hot blast in 1828.

Dr. Joule,of Manchester, England, read his first paper on the mechanical equivalent of heat in the year 1843, and the results of his experiments was communicated to the Royal Society in 1849.

In the year 1856, Henry Bessemer proposed a method of producing steel at a low cost, and by the year 1862, this method had established itself in a commercial way.

The Siemens Gas Producer was brought out about the year 1863, also the Open Hearth Furnace.

In 1878, Mr. J. E. Dowson devised a complete gas plant for the use of fuel gas in the gas engine, and in 1881, read his first paper before the British Association for the Advancement of Science, at which he exhibited a gas plant working a 3 H. P. Otto gas engine. It was at this meeting that the late Sir Frederick Bramwell made his memorable prophecy that in 50 years the gas engine would have superseded the steam engine.

The Suction Gas Generator and Engine was perfected by the Frenchman, Benier, in 1894.

During the past year some of the patents relating to the manufacture of aluminum expired. We may expect to see new capital engage in the production of this useful metal, locating the factories near the raw material and fuel supplies, generating electricity with gas engines, with by-product recovery gas generators, at a cost which will be lower than has been attained in the past. Aluminum has been replacing copper in electrical apparatus, and it may be that its use will increase.

LIFT BRIDGES

A DISCUSSION

MR. H. S. PRICHARD:* A discussion of Lift Bridges involves some comparison with, and therefore some consideration of, other forms of movable bridges.

In designing movable bridges the ordinary principles of safety, and the general principles of economy, as ably presented by Mr. Emil Gerber in his paper on "Some Commercial Features of Structural Engineering,"† should, of course, be observed, but it is not admissible to go further and lay down numerous requirements as essential for a movable bridge. For instance, if the dictum that "the bridge must cause the least possible delay to the traffic crossing it and to the traffic using the navigable channel" were applicable to all cases, such bridges as the pontoon bridge across the Hooghly at Calcutta could not be permitted. An opening 200 feet wide, for the passage of ships, is made in this bridge by removing, when occasion requires, four of the pontoons with their superstructure, and shearing them clear of the opening. As the bridge is only opened twice a week and as it ordinarily takes 15 minutes to open and 20 minutes to close it, both the traffic through and the traffic over it are much delayed, yet what engineer would condemn this arangement without first ascertaining that it would be truly economical as well as practicable to improve on it?

A bridge company desiring to know how some novel features were working in a railroad swing bridge erected a year previous made inquiry, and was informed that the bridge had not been opened. Incidents of this kind are not uncommon, as the United States Government rightfully requires movable bridges in numerous cases where the waterways are little used. To insist on the same requirements for such cases as for those where the traffic is congested would be wholly

* Statistician, American Bridge Company, Pittsburgh, Pa.

† Proceedings Engineers' Soc. W. Pa., April, 1907.

Presented before the Structural Section, November 10, 1908, and published in the February, 1909, Proceedings.

unreasonable. The fact is each case should be judged by itself both as to type of bridge and details of design, in accordance with the conditions under which it will be used, the site and environment. No one type is the best for all cases, and bridges which are admirably adapted to the conditions in one case may be wholly unsuitable in others.

In ancient and medieval times the chief consideration in making bridges movable was to prevent the invasion or pursuit of an enemy. This consideration was so important that even the Romans did not consider themselves strong enough to risk permanently fixed bridges until 142 B. C., after the conquest of Etruria and the defeat of Hannibal. Long before this, however, they had built a wooden drawbridge called the Pons Sublicius.

The same considerations which influenced the Romans led the nobles in the Thirteenth century to introduce horizontal swing bridges, and in the Fourteenth century hinged lift bridges, at the entrances to their castles.

Changes in the conditions of life and methods of warfare have done away with the advantage of making bridges movable as a defensive precaution, but the development of transportation and intercourse on land and water have introduced new and cogent reasons for constructing movable bridges, and the character of the traffic, site, environment, and available resources have confronted engineers with many difficult problems in solving which numerous types of movable bridges have been developed.

There is little uniformity in the names given by different authorities to different types of movable bridges, and in some cases the same term is specifically applied by different authors to radically different types. For instance, the term drawbridge is sometimes used as a general name for any movable bridge, sometimes it is restricted to horizontal swing bridges with unequal arms, sometimes to hinged lift bridges, and sometimes to bridges which are not pivoted, but are bodily drawn back. In a general way movable bridges can be roughly classified as: Horizontal Swing Bridges, Horizontal Rolling Draw-bridges, Ferry Bridges, Floating Bridges,

Straight Lift Bridges, Hinged Lift Bridges and Rolling Lift Bridges.

Many of these types are built either as single or double leaf bridges; that is, the opening is spanned either by one movable leaf or arm or by two distinct leaves or arms, which, when the bridge is closed, meet at or near the center of the waterway.

The simplicity and low cost of the construction and operation of horizontal swing bridges are considerations of great weight, and deciding ones in many instances. It is a mistake to suppose, as is sometimes claimed, that such bridges are fundamentally wrong in principle. They have some features, however, which are objectionable or prohibitory in certain cases: If the pivot is on the shore they take up considerable shore space; parallel bridges cannot be placed closer together than the combined length of one arm of each bridge; additional tracks or roadway cannot be added to an existing bridge without entirely rebuilding it; and each additional foot of increase in width either necessitates a corresponding increase in length or cuts down the clear waterway.

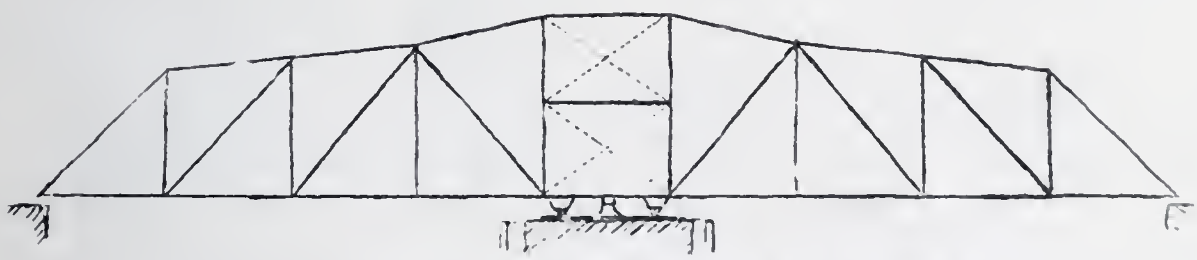

Fig. 1. Horizontal Swing Bridge with equal arms.

For many years the horizontal swing bridges constructed far outnumbered movable bridges of other types. There are many varieties of this type of bridge, the most common being horizontal swing bridges with equal, balanced arms, usually made partly continuous over the center support, but sometimes composed of two simple spans connected by rods to a central tower, the rods being slack when the bridge is closed, but brought into tension by the application of power until the ends of the bridge are lifted clear of the abutments before it is swung, as in Fig. 1. The Baltimore & Ohio Railroad bridge

over the Arthur Hill, on Staten Island, is of this type, and is described in the Railroad Gazette, June 22, 1888.

Single leaf horizontal swing bridges are frequently built with one long and one counterbalanced short arm. The simplest form of movable bridge, of which the speaker has knowledge, is illustrated by an old bridge which spans a canal near Bordentown, N. J. It is a single leaf horizontal swing bridge with a counterbalanced short arm. The pivot is located on the opposite shore to the tow path, and, together with the track, is slightly inclined toward the canal, as in Fig. 2, so that whichever way the bridge is opened its center of gravity, which is between the pivot and the canal, is slightly raised. The bridge has no one to tend it, but is pushed open on occasion by the bow of an advancing canal boat and is closed by gravity after the boat has passed. Many bridges similar in principle to the one at Bordentown, but with a different arangement of the turntable, are in use on the Ohio State canals, and new ones are built as occasion requires.

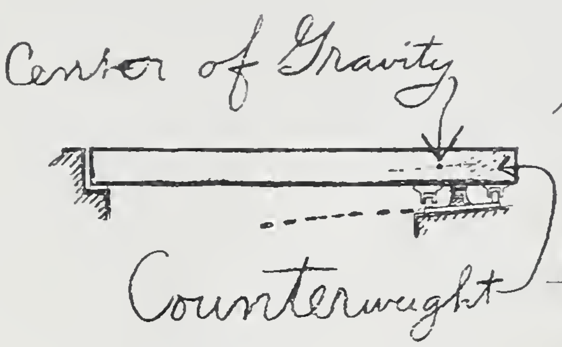

Fig. 2. Horizontal Automatic Swing Bridge.

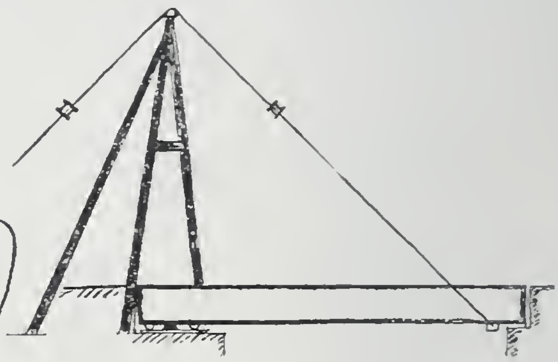

Fig. 3. Suspended Single Arm Swing Bridge

In some cases single leaf horizontal swing bridges are built with a single arm, of which one end rests on a pivot or set of rollers and the other is supported by diagonal rods, which hang from a point in a tower or guyed tripod directly above the pivot, as in Fig. 3. There are a number of bridges of this type, both railway and highway, across the canals at Trenton, N. J., which have been in satisfactory service for many years, were low in first cost, and admirably adapted to the traffic and site at the time they were built. One of the deck railroad bridges of this type at Trenton, N. J., had no

bracing between the girders, which were connected by hinged struts and ties. The girders closed on each other like the arms of a parallel ruler, when the bridge was opened, thereby increasing the waterway. The structure lacked stiffness, was not very satisfactory, and was finally replaced.

Double leaf horizontal swing bridges consist of two structures, which, when closed, are locked together over the channel and locked to the abutment at their shore ends, as in Fig. 4. There is a highway bridge of this type at Cleveland, Ohio, illustrated and described in Engineering News, August 8, 1895.

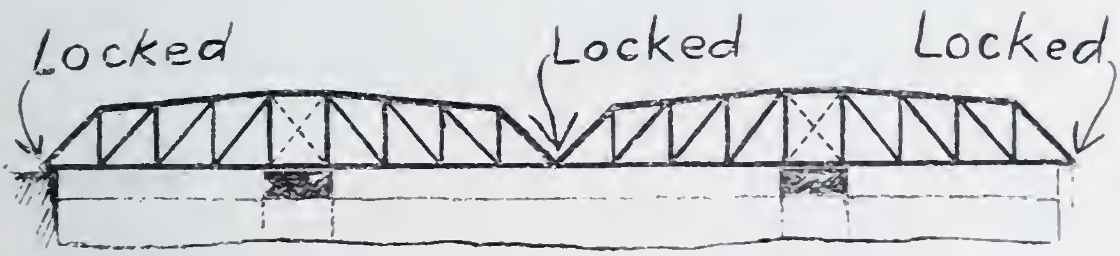

Fig. 4. Double Leaf Horizontal Swing Bridge.

A single leaf swing bridge was built not long since, in which the end opposite to the pivot was supported by columns which traveled on a submerged track. The rack and pinion were also submerged. It was not a success.

Horizontal Rolling Draw Bridges are sometimes built with single and sometimes with double leaves or arms, which draw back to one or to opposite sides of the channel. When Horizontal Rolling Draw Bridges are arranged to be rolled back diagonally, as in Fig. 5, they take up considerable shore

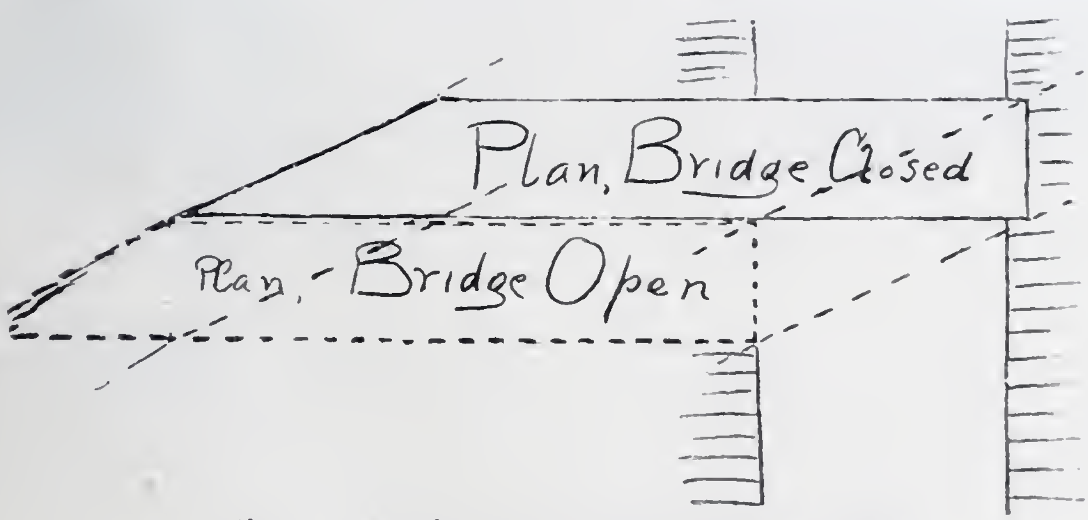

Fig. 5. Horizontal Rolling Draw Bridge.

space. When they are drawn back in the direction of the road the problem is encountered of avoiding interference between the road and the roadway of the bridge. This problem is variously solved, but it would be too much of a diversion from the subject of the evening to discuss it.

Ferry Bridges are used as an expedient in cases of long crossings where high bridges, with approaches, or swing or lift bridges would be impracticable or too expensive. They consist of platform cars which travel to and fro between opposite shores, and are suspended from a bridge of sufficient height to clear all boats using the waterway. A bridge of this type at Duluth is described in Engineering News, March 20, 1902; Railroad Gazette, March 14, 1902, and Transactions Am. Soc. C. E., 1905, Vol. LV, page 322.

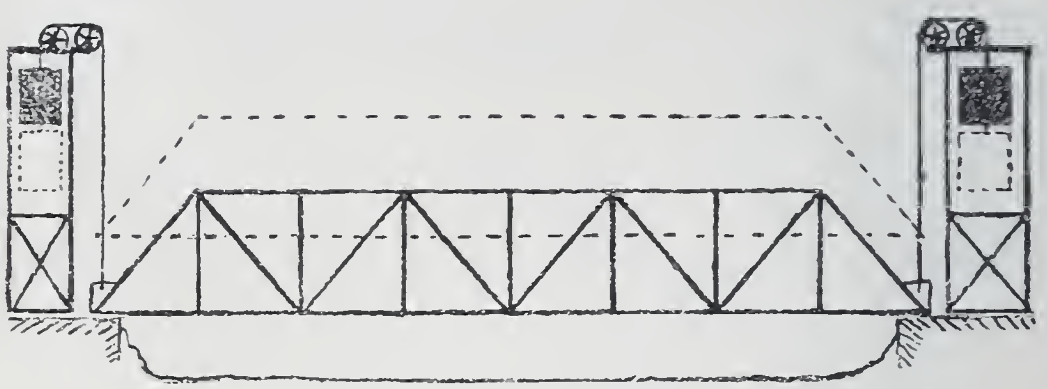

Fig. 6. Vertical Lift Bridge.

Floating Bridges are seldom used. The following description has been given of a floating bridge designed by Mr. Mallet to cross the Royal Canal at the Broadstone terminus of the Midland Great Western Railway of Ireland:

> "The general idea is that of a pontoon or flat-bottomed boat of iron. When the bridge is in place, water is admitted until it settles down firmly on timber wall-plates. To open it the water is drawn off by a movable siphon. The bridge then floats, and is drawn into a recess, leaving the passage clear along the canal."

Mr. Robert A. Cummings, of this Society, described to the writer a design he proposed, on a certain occasion, for a single leaf swing bridge, the pivot end of which rested on a solid foundation and the opposite end on a movable float.

Lift Bridges, which form the special topic for discussion this evening, have come very much into favor and have largely increased in number during the last fifteen years. This has been caused principally by the congested condition of land

Fig. 7. Halsted Street Lift Bridge, Chicago.

and water traffic and the high value of real estate in the large cities, which made it advisable to build bridges which required less area than those of the swinging type, and which stimulated engineers to devise new types and improved details of

design for old ones. Many of these types and devices are protected by patents.

Straight Lift Bridges, or Vertical Lift Bridges, as they are sometimes called, are those which are lifted bodily without changing their horizontal position, usually from towers at each end of the bridge by means of cables or chains, which are attached to the brige at its four corners, run over sheaves at the tops of the towers and have counterweights, suspended in the towers, attached to their opposite ends, as in Fig. 6. Such bridges have been used for many years over the Erie Canal, and several have been elsewhere erected. A number are under construction at the present time. The largest bridge of this type is the Halsted Street Lift Bridge, Fig. 7, over the Chicago River, designed by J. A. L. Waddell and built in 1893. It is a highway bridge of 130 feet span, 50 feet roadway and has a lift of 141 feet. It is described in Transactions, Am. Soc. C. E., January, 1895, Vol. 33.

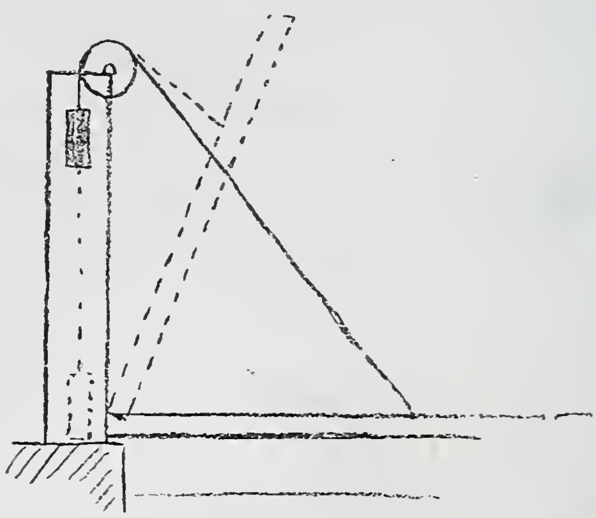

Fig. 8. Original form of Hinged Lift Bridge.

The economy of the straight lift bridge varies, in accordance with the head room required for navigation, in proportion to the clear opening. It has the advantage over other types of not having to be opened or closed against the direct horizontal action of the wind, though the tendency of the wind to sway the bridge out of its position has to be considered. It has the further advantage that both ends can be built on a skew.

An old straight lift bridge, which has since been replaced over the Royal Canal, Dublin, Ireland, was balanced by a counterpoise consisting of a tank filled with water.

Fig. 9. Hinged Lift Bridge over Harlem River.

The original form of Hinged Lift Bridge was probably a simple platform, one end of which was hinged, and which was raised by means of ropes or cables attached to the opposite end and run over sheaves in a tower or wall directly above the hinged end, as in Fig. 8. In Fig. 9 is shown a modern instance of a double track railroad bridge of this type used as a temporary bridge over Harlem River, New York. The addition of a counterweight to the end of the rope or chain was a natural development. The difficulty in counterweighting such a bridge lies in the fact that the counterweight required decreases as the bridge is opened. Various means have been devised for overcoming this difficulty. One of the methods is to have the counterweight travel on a track so curved that its pull on the cable in any position just balances the pull which the cable receives from the bridge, as in Fig. 10.

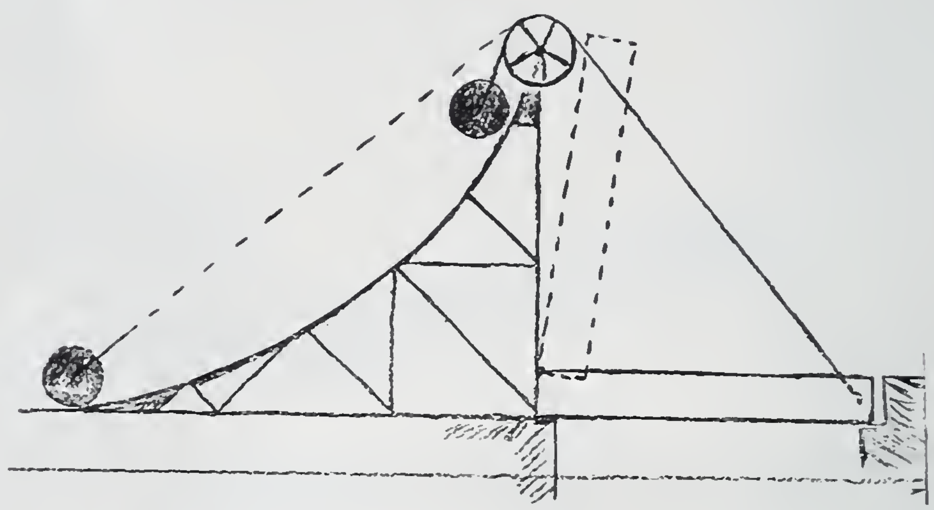

Fig. 10. An old type of Lift Bridge.

Quite a number of bridges of this kind have been built, but the device is not much used at present. In a bridge built in San Domingo, a balance was maintained between the bridge and the counterweight by means of a conical drum at the foot of the tower, the chain from the bridge being attached to the small end of the drum and the chain from the counterweight to the large end; thence running over a sheave at the top of the tower to a connection with the counterweight. An ingenious method of equalizing the pull on the cable from the bridge and the counterweight has recently been devised and patented by Mr. L. H. Shoemaker. This device, which, to use the vernacular, is the latest thing in lift bridges, consists

of a sheave placed on the cable between the tower and the ends of the bridge, connected by a movable arm to the pin in the tower about which the girder rotates, as in Fig. 11. As the bridge is raised the angle of the cable is changed, thereby maintaining in it a nearly constant pull from the girder. No bridges have yet been built from this design which is very recent and has much to commend it.

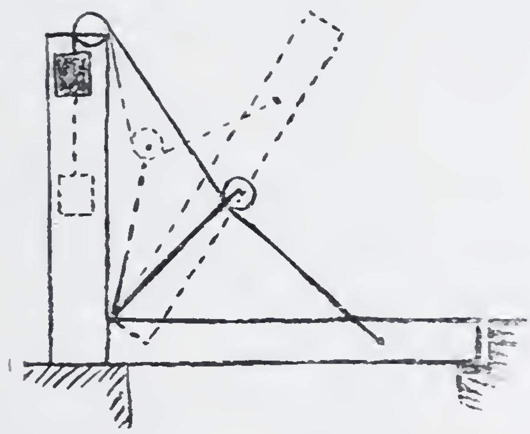

Fig. 11. Shoemaker's Lift Bridg .

Another method of equalizing the pull on the cable is to divide the counterweight into a number of parts which come to a rest and relieve the cable of their weight one after the other as the bridge is raised.

The Brown Bascule Bridge, shown in Fig. 12, is a Hinged Lift Bridge, in which one end of the movable leaf is hinged at "C," and the leaf is raised by counterweighted cables which run over sheaves at the top of a tower back of the hinged end, and over curved guides, E-F, attached to the trusses, or girders, of the movable leaf. The path of the guides is such that the pull on the cables from the weight of the leaf, is equal to the pull from the counterweight. The bridge is raised by hydraulic power applied at "B." The movements of the various parts are as follows: The bridge rotates about a movable point, "C;" point "B" runs in a horizontal line outward; "D," with the rest of the bridge moves in a curve around the moving point, "C," which point moves in the arc of a circle around point "A," controlled in vertical travel by the fixed strut, "B-C." The bridge is balanced by the counterweights until an angle of 81 degrees is passed after which the cables

come into contact with another set of curved guides running from "F." to "G," so that further movement raises the counterweights which thus act as automatic brakes and prevent the bridge from striking the tower. A single leaf bridge of this type, with a clear waterway of 140 ft., known as the Ohio Street Bridge, was erected in Buffalo in 1905, and is described in Engineering News, January 16, 1908.

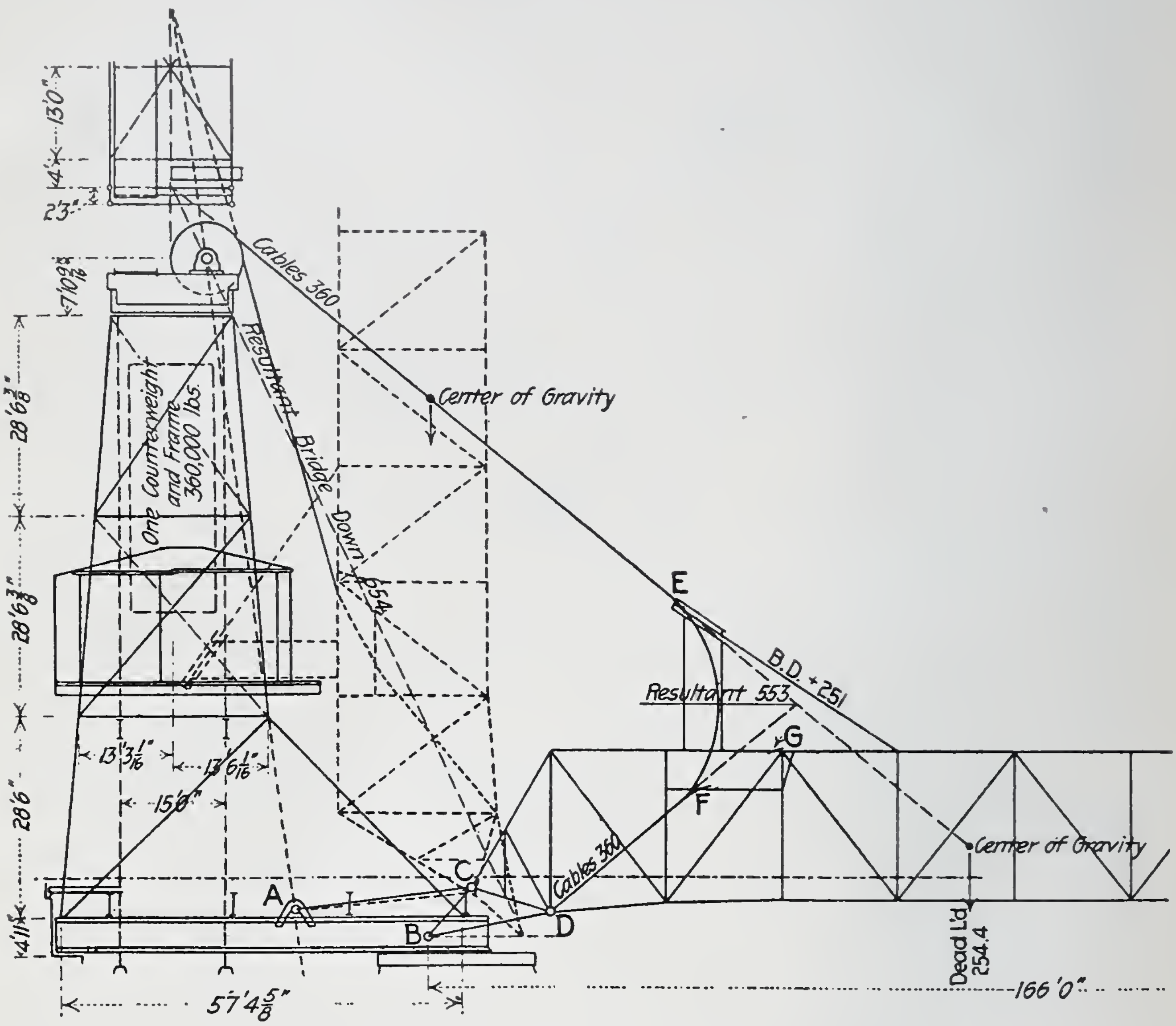

Fig. 12. Brown Bascule Hinged Lift Bridge.

Hinged Lift Bridges with tail arms, to which counterweights are rigidly fixed, as in Fig. 13, are one of the simplest and, when there is plenty of height above the water, one of the most attractive forms of lift bridges. The pin which forms the hinge is usually firmly attached to the girders like the trunnions of a gun, and revolves in supporting journal boxes, hence the name trunnion bridges.

Trunnion lift bridges, with counterweights fixed to their tail arms may be called " fixed counterpoise trunnion bridges."

They are built with both single and double leaves. The roadway between the tail arms is generaly a fixed structure, independent of the movable leaves, as in Fig. 14, so that the live load on that portion of the bridge will have no tendency to tilt the leaves.

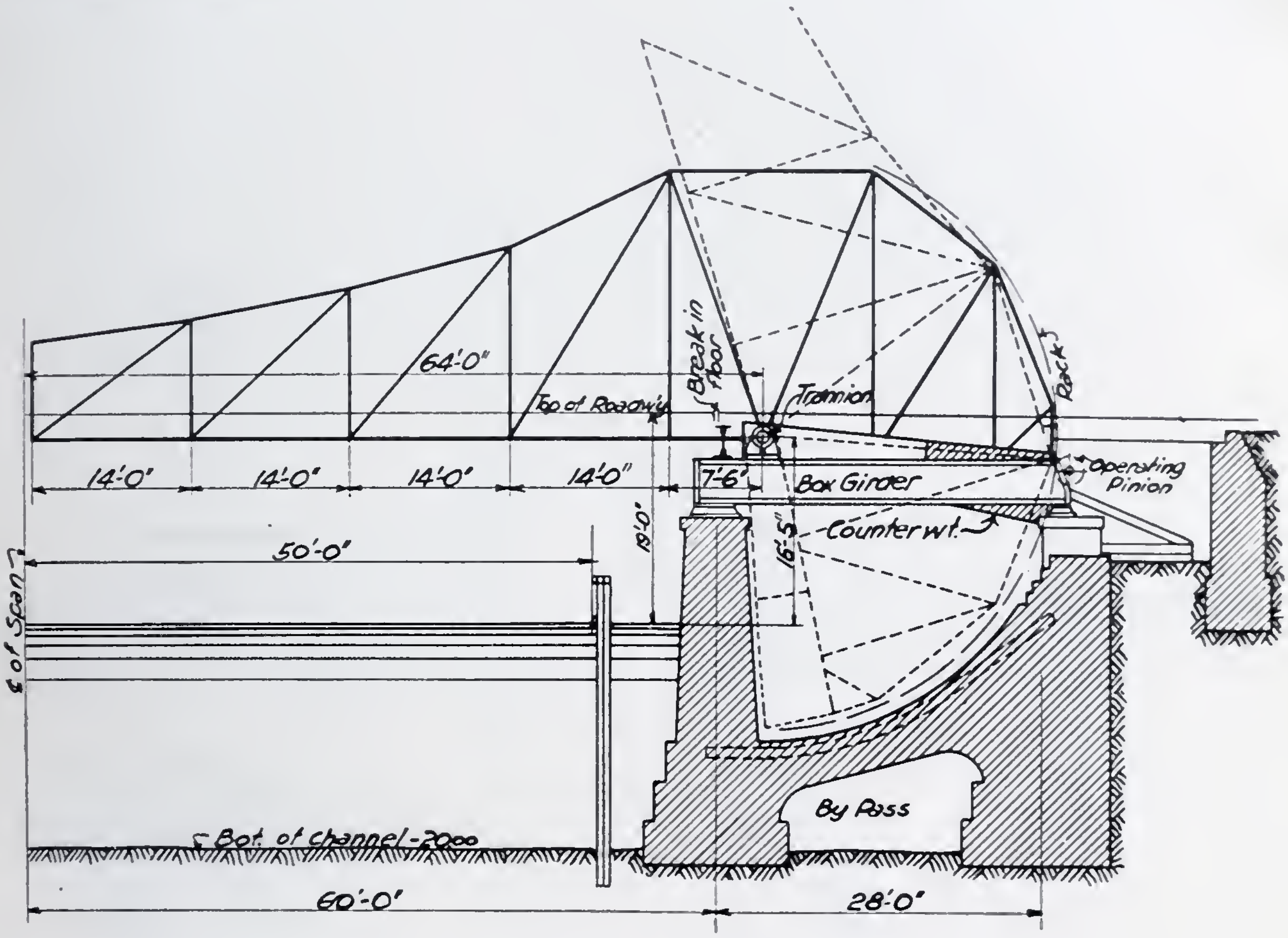

Fig. 13. Trunnion Lift Bridge.

The famous tower bridge in London, which cost something over $4,000,000, and provides a waterway of 200 ft. in width, has two symmetrical leaves with fixed counterweights attached to their tail arms. In addition it has a high level fixed bridge at the top of the towers, as in Fig. 15, to which foot passengers are conveyed by elevators when the lower bridge is opened. This arrangement of a high bridge served by elevators is capable of being extended to include vehicles and street cars. In cases in which the waterway is in constant or very frequent use and real estate at the approaches is very expensive, a high bridge served by elevators for all kinds of city traffic would have its advantages.

In hinged lift bridges with counterweighted tail arms, the trunnions are generally designed to be placed in the cen-

ter of gravity of the movable leaves, so that the leaves will be in equilibrium in any position.

The exigencies of the design of fixed counterpoise trunnion bridges, and of most of the other forms of hinged lift bridges, make it necessary to place the hinge some distance back from the clear waterway, thereby increasing the length of the long arm of the movable leaf. To reduce the span for the live load it is customary to place a support for the closed arm as near as practicable to the waterway. In the case of bridges with two leaves designed to support the live load on the principle of the cantilever, these additional supports increase the leverage of the anchorages and counterweights.

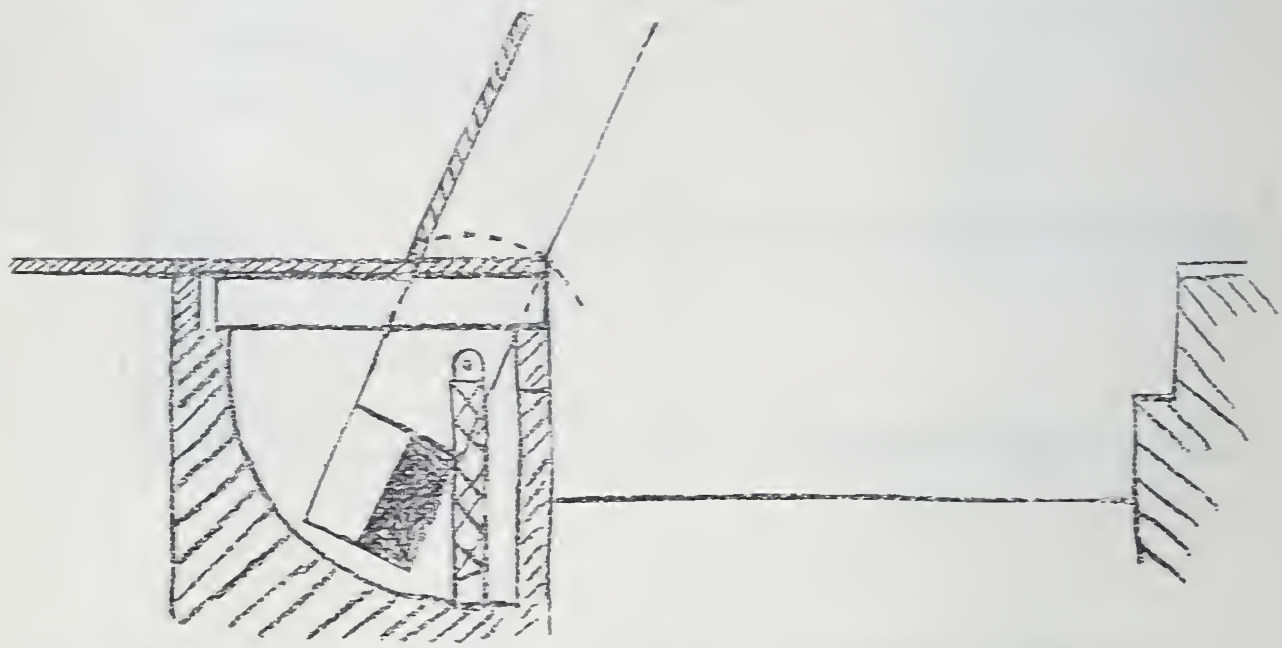

Fig. 14. Ordinary arrangement of Roadway in Trunnion Bridges.

When there is not much height between the top of the water and the roadway, there is very little room in which to place a fixed counterweight, which makes it necessary to construct a pit in the masonry into which the tail arm can revolve, and to make the counterweight quite heavy in order to keep the tail arms as short and the pit as small as practicable. A fixed overhead counterweight is impracticable, as it would throw the center of gravity of the movable leaf too far above its bottom flanges and would swing back to an interference with the roadway of the approaches.

To obtain the advantage of overhead counterweights, to overcome the tipping of underneath counterweights toward

the water or bottom of the pit in opening the bridge, and to facilitate the final adjustment of each counterweight by definitely fixing the point where it acts on the movable leaf. The Strauss Bascule and Concrete Bridge Company,* build a bridge known as the "Strauss Trunnion Bascule Bridge," in which the counterweight is attached to the tail arm of each girder by a single pin, and is so restrained that any vertical or horizontal surface or section remains vertical or horizontal during the opening and closing of the bridge. This method of attaching the counterweights, which is termed pivoting, admits of a variety of designs, some with underneath

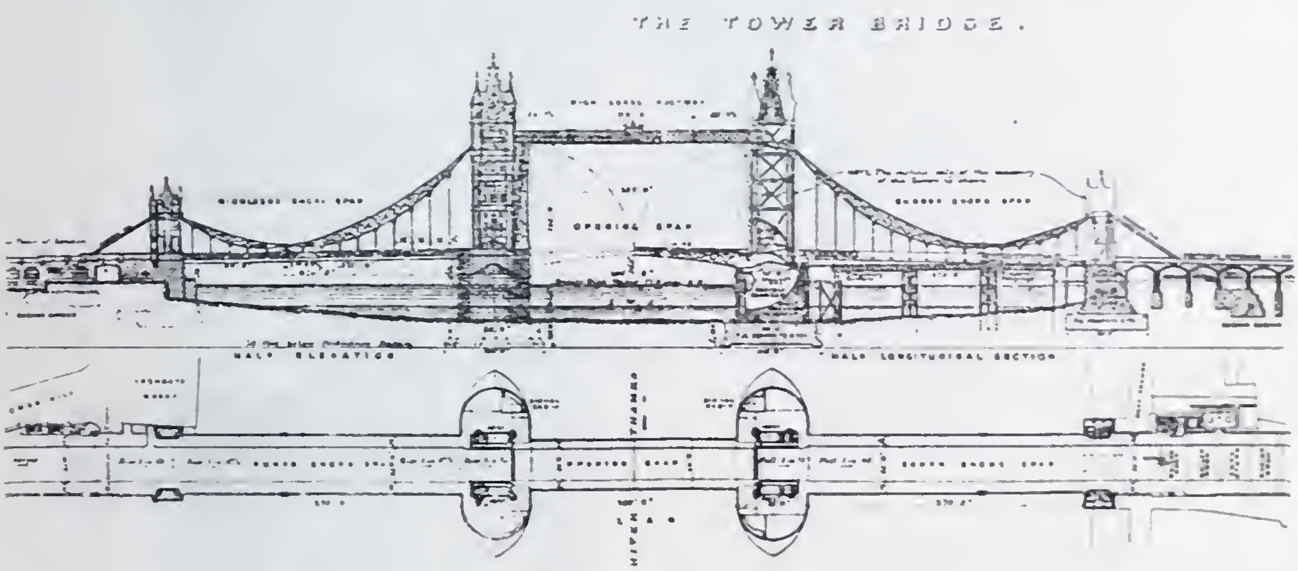

Fig 15. The Tower Bridge, London.

and some with overhead counterweights. The principle is indicated in Fig. 16, which shows an overhead counterweight pivoted to the end of the tail arm, and maintained in a vertical position by a movable strut, the opposite end of which is attached by a pin to a fixed tower. An excellent paper on the Struss Trunnion Bascule Bridge, by Mr. Philip L. Kaufman, appeared in the April, 1908, number of the Mechanical and Electrical Engineering Record, published by the State University of Kentucky, and has been reprinted in a neat pamphlet. The Strauss Bascule and Concrete Bridge Company have issued a handsome catalogue and supplementary bulletin listing 13 of their single and double leaf Bascule Bridges completed or under construction 1905 to 1907, illustrating a number of them, and describing the general prin-

* 902-904 Fort Dearborn Building, Chicago, Ill.

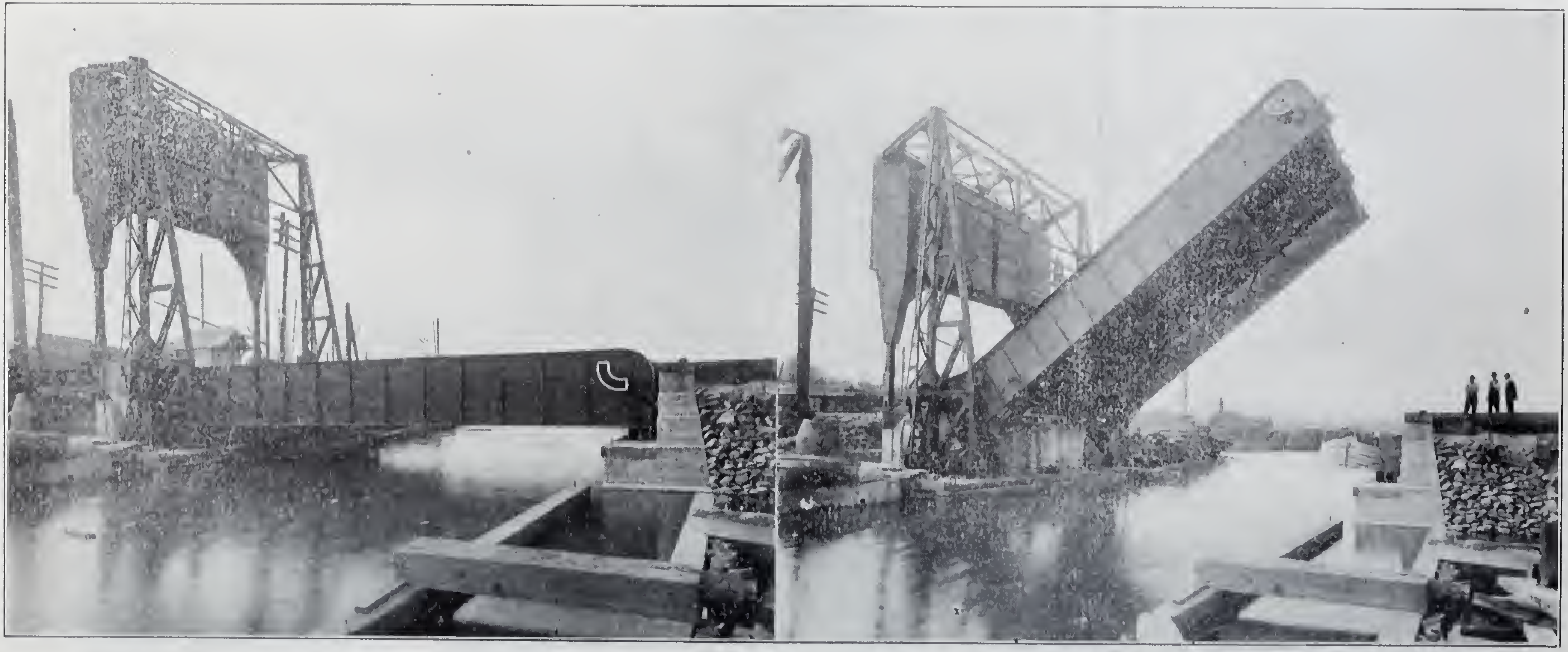

Fig. 16. A Strauss Bascule Type with Pivoted Counterweight. Baltimore & Ohio Railroad Bridge at Staten Island, New York.

ciples of their designs. One of their bridges, the W. & L. E. R. R. bridge at Cleveland, Ohio, is described in the Railway and Engineering Review, December 16, 1905.

Quite recently the Strauss Company have developed another design, shown in Fig. 17, in which the counterweight is fixed in a movable frame hinged to the top of a tower to the rear of the movable leaf and connected to it by links. The movable frame and movable leaf are arranged to rotate in harmony, the center of gravity of the one falling as the center of gravity of the other rises. This arrangemnet makes it possible to place the trunnion quite close to the waterway, thus reducing the span to a minimum. Mr. Strauss informed the speaker that the arrangement is an economical one.

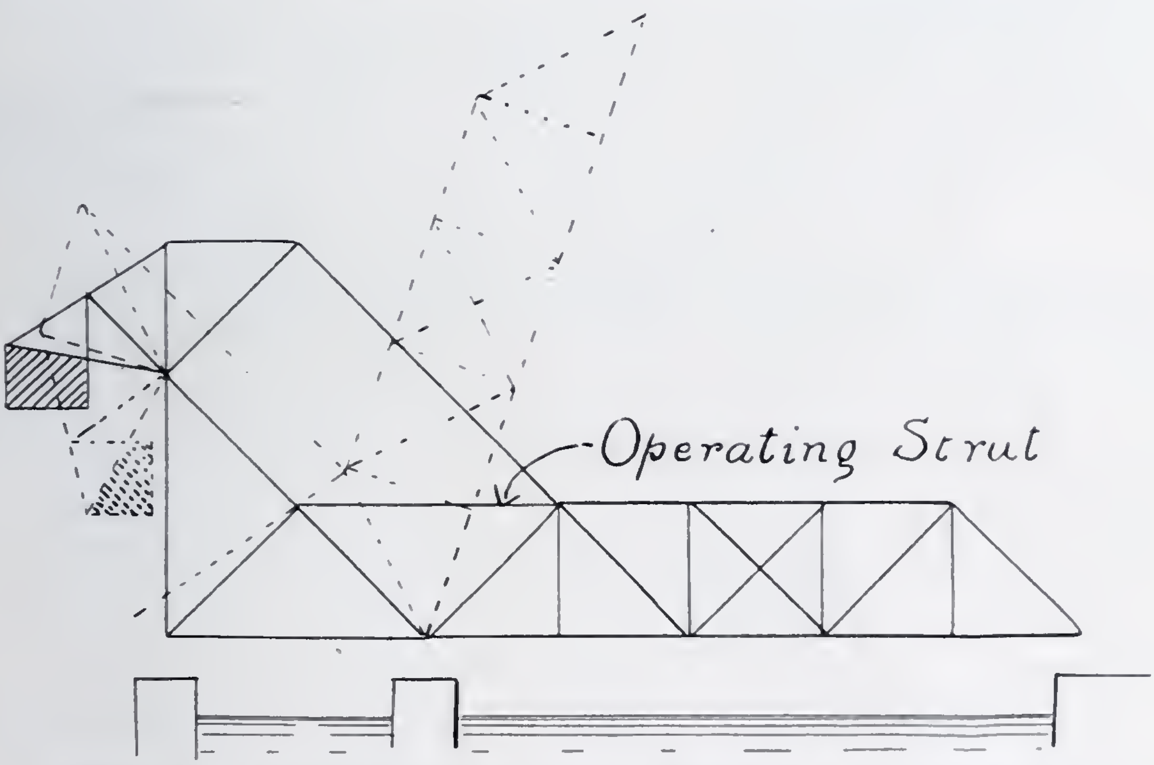

Fig. 17. A Strauss Bascule Type with Fixed Counterweight in Movable Frame.

The Page Bascule Bridge, as arranged for through spans, has a counterweight in a swinging frame of which one end is hinged to a fixed point in the rear, and the other rolls on a curved track attached to the movable leaf, as in Fig. 18. For deck bridges an approach span can be used for the swinging frame. The Page Bascule Railroad Bridge over the Chicago River, at Bridgeport, Chicago, is described in The Railway and Engineering Review, October 26, 1907.

A type known as the "Borg Bascule Bridge," is shown in Fig. 19. Its special features, as described by the George W. Jackson Company,* are its direct acting mechanism, and the pivoting of the movable leaf. "Two gudgeons in broad bearings form the pivots and are so connected across the leaf as to make a continuous transverse shaft, holding the leaf rigidly in position." The Franklin Street Bridge, Michigan City, Ind., of this type, is described in The Engineering Record of July 25, 1908.

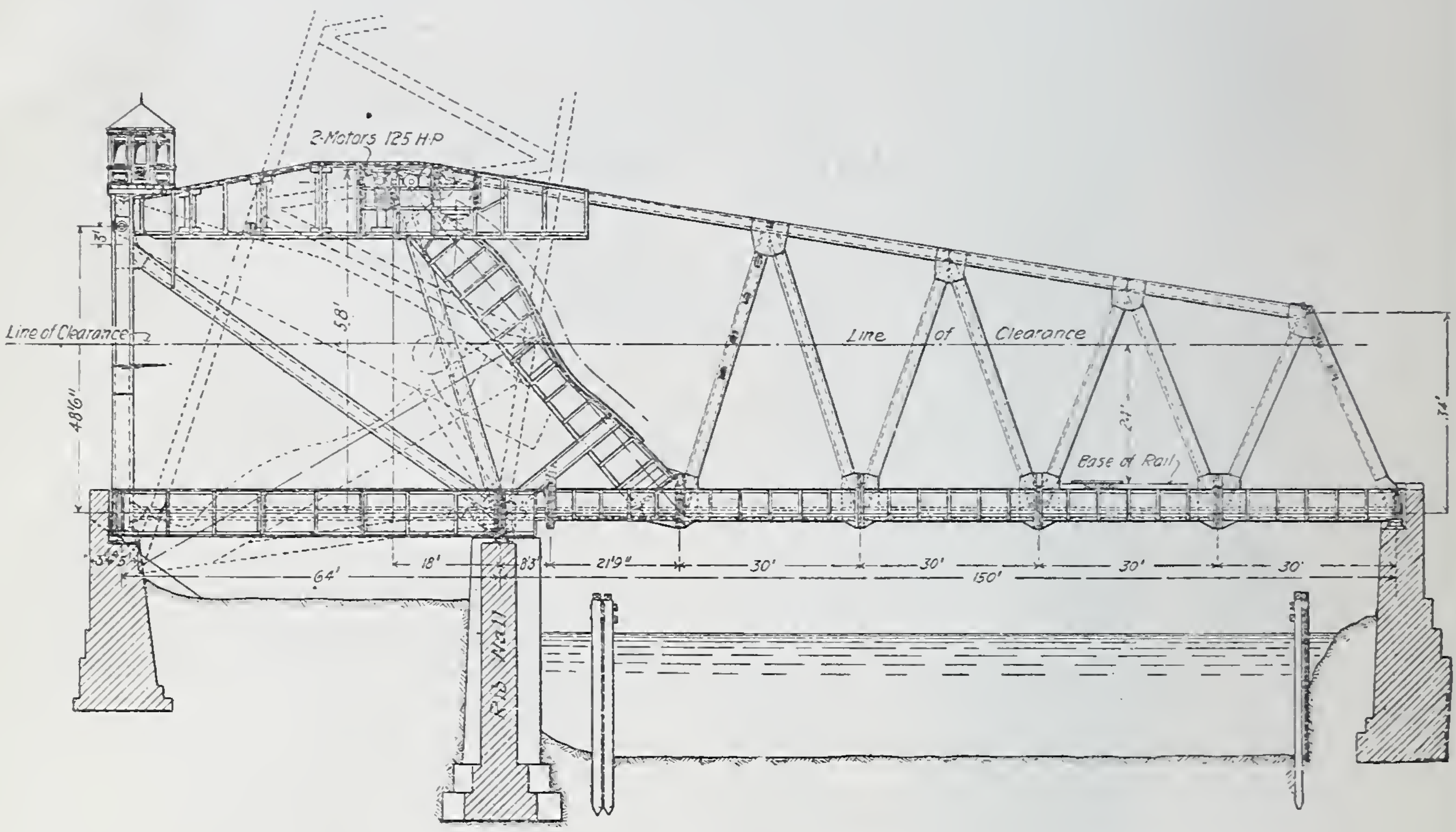

Fig. 18. Page Bascule Bridge.

If, as stated in the Strauss catalogue, the earliest case of a hinged lift bridge with a fixed counterweight on a short arm was the double leaf Bascule of the Northeastern Railway, built at Selby, England, in 1839, the rolling lift bridge is an older type than the hinged lift bridge with counterweighted tail arms.

Mr. K. Hellenthal, in the paper on "Some Old Examples of Bascule Bridges,"† has transferred accounts of two rolling lift bridges with movable axis of rotation, from the "Handbuch der Ingenieurwissenschaft"—a German publication. In the

* 169-179 W. Jackson Boulevard, Chicago, Ill.
† Jour. of the W. Soc. of Engrs. Vol. 6, p. 468.

first bridge, which "was built at Havre, in France, before 1824, by Lomblardie," the axis of rotation is replaced by toothed sections whose centers coincide with the center of rotation and whose circumference rolls on toothed racks, which are placed on the side walls, so that the center of gravity of the whole system moves in a horizontal line; as in Fig. 20. Mr Hellenthal calls attention to the resemblance between this old bridge and the modern "Scherzer Rolling Lift Bridge."

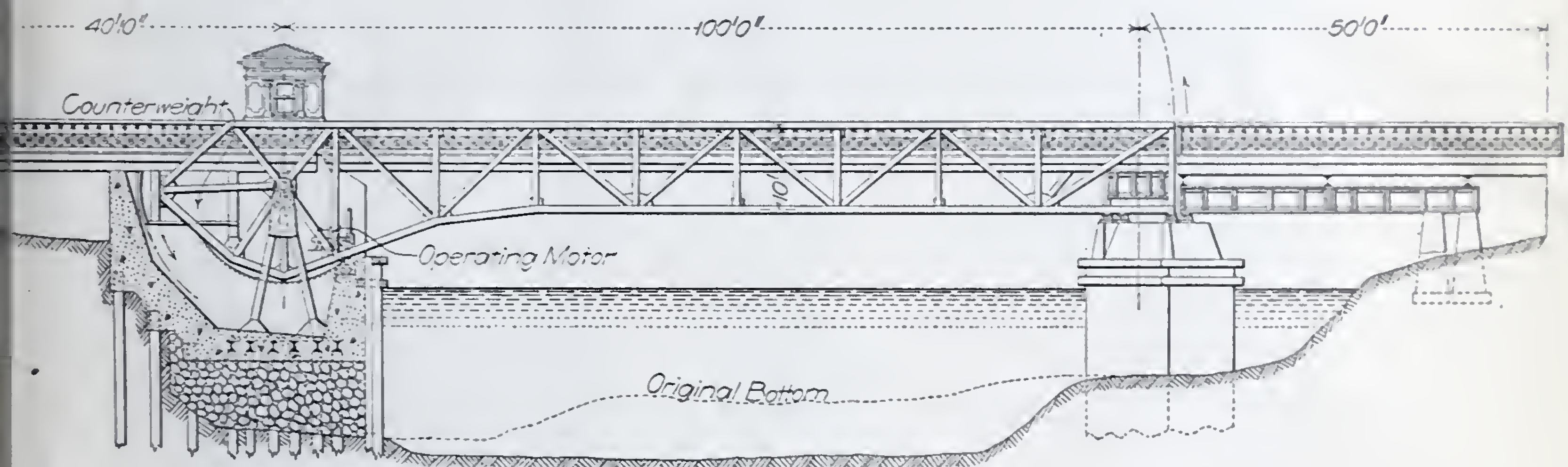

Fig. 19. Borg Bascule Bridge, Franklin Street, Michigan City, Ind.

The Scherzer Rolling Lift Bridges have movable leaves with tail arms to which fixed counterweights are rigidly attached. The lower portion of the tail arm, beginning at a point where the leaf rests on the abutment, is in the form of an arc of a circle, as in Figs. 21 and 22, so that when the bridge is opened the leaf rolls back, like a huge roller, on a horizontal track on the abutment. This arangement gives a minimum length of long arm.

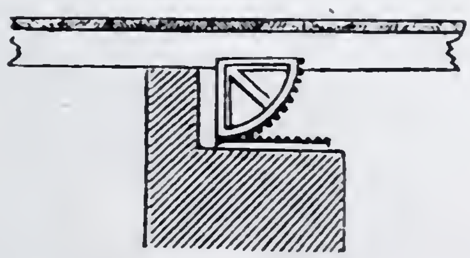

Fig. 20. Old Type of Rolling Lift Bridge, described by Hellenthal.

The Scherzer Rolling Bridge can be so arranged and the radius of the rolling surface so chosen that the center of gravity will be in the axis of rotation, in which case the moving leaf will be in equilibrium in any position. The Scherzer Rolling Lift Bridge Company, however, arranged the leaf

Fig. 21. Scherzer Rolling Lift Bridge. N. & S. S. Ry Co., Cleveland, Ohio.

Fig. 22. Scherzer Rolling Lift Bridge, North Halsted Street, Chicago.

in some of their bridges so that it is at rest when at an inclination of 45 degrees, and will have to be locked down when the bridge is closed. When the lock is released, the leaf tends to rotate to a 45 degree position and as much beyond as its momentum will carry it. Similarly it has to be held in its extreme open position and tends, when released, to fall back to a 45 degree position and as much lower as its momentum will carry it. This scheme could likewise be applied to Hinged Lift Bridges with counterweighted tail arms. Its advantages and disadvantages afford a good theme for discussion. The facts that under this arrangement the weight of the leaf tends to facilitate both the opening and closing of the bridge and that it acts like a brake as the moving leaf approaches its extreme positions are points in its favor. On the other hand the fact that the leaf has to be locked to keep it down is certainly no advantage to the closed bridge. A large number of Scherzer Rolling Lift Bridges have been built since 1893, many of which are described and illustrated in a handsome cloth-bound catalogue published by the Scherzer Rolling Lift Bridge Company.* Descriptions and illustrations of a number of these bridges also appear in technical publications.

A number of bridges of a type known as the "Rall Bascule Bridge," have been built by the Strobel Steel Construction Company.† These bridges have movable leaves with fixed counterweights attached to their tail arms, and are partly hinged or trunnion lift bridges and partly rolling lift bridges. In this type the movable leaf, when the bridge is closed, rests on a supporting pivot as close as practicable to the clear waterway. It is also connected to the pivot by a swinging strut. At its center of gravity the leaf is connected to rollers, which, when the bridge is closed, are slightly above a horizontal track, as shown in Fig. 23. When the bridge is opened the leaf first rotates about the pivot until the roller comes to a bearing on the track after which it rolls back from the waterway. The bridge is arranged to give the minimum travel necessary for clearance. As the rollers are placed vertically above the pivot

* Monadnock Block, Chicago, Ill.

† 1744 Monadnock Block, Chicago, Ill.

Fig. 23. Rall Bascule Bridge at Peoria, Ill. Built by Strobel Steel Construction Company.

(in the center of gravity), and as high as it is practicable to throw the center of gravity, the leaf can be designed with the maximum length of tail arm and maximum leverage of counterweight. A description and illustration of one of these bridges, recently completed at Peoria, Ill., is given in the Railroad Gazette, July 5, 1907.

A bridge of a type known as the Cowing Lift Bridge, designed by John P. Cowing,* which has been built at Cleveland, Ohio, has a tail arm with fixed counterweight and rotates about a fixed axis, but in place of trunnions its tail arm has the form of a circular arc and rests on rollers, which are arranged in a nest to form a corresponding arc, as shown in Figs. 24, 25 and 26. A description of this bridge has been furnished by Mr. Cowing for this discussion.

In the second old bridge, "by Ardagh," described by Mr. Hellenthal, in the paper previously referred to, each truss or girder is suspended by a rod, of which one end is attached to a fixed pivot above the rolling end of the bridge and the other is attached to a point in the girder between its center of gravity and its rolling end. In opening, this point travels in a curved path with the fixed pivot as the center, and the rolling end follows a curved track so adjusted that the center of gravity of the girder moves in a horizontal line, as in Fig. 27. Mr. Hellenthal points out that this old design is similar to the modern Schinke type. Two bridges of this type have been built in Milwaukee and are described in Engineering News, March 7, 1895, and April 22, 1897. The first of these bridges is similar in principle to the old bridge shown in Fig. 27, but is supported by a strut instead of hung by a link. In the second bridge the curved track is in the moving leaf, and the roller is on the abutment, as shown in Fig. 28.

A bridge termed "Gyratory Lift Bridge," has been patented by Eric Swensson, and is shown in Fig. 29. It has a long longitudinal axis of rotation and is hung from two towers at opposite sides of the waterway by two trunnions, which rest on journals at the tops of the towers. In revolving around its longitudinal axis the bridge turns upside down, as shown. The bridge is counterweighted to bring the center of gravity in the axis of rotation.

* Hippodrome Building, Cleveland, Ohio.

Fig. 24. Cowing Lift Bridge, Jefferson Street, Cleveland, Ohio.

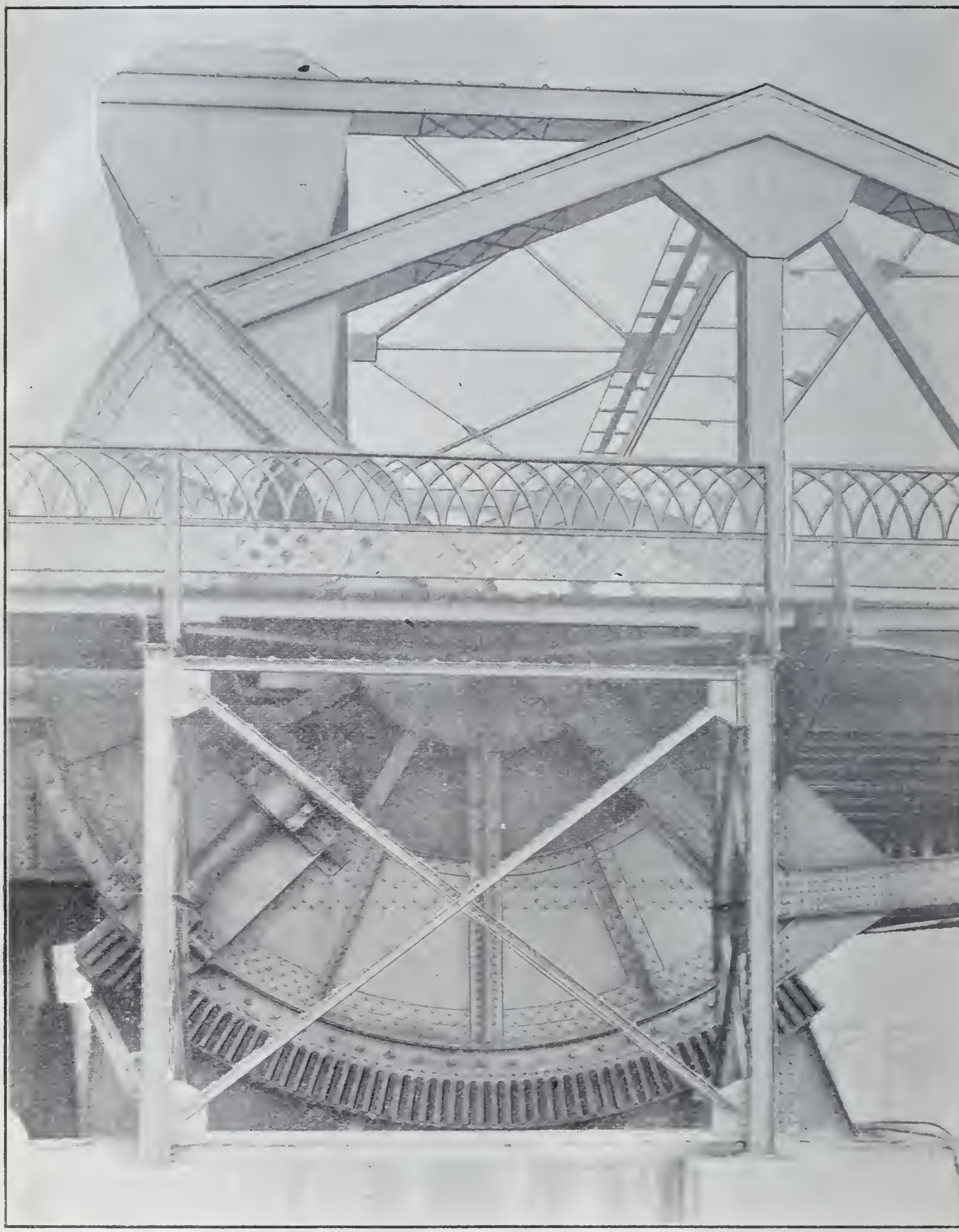

Fig. 25. Details of Cowing Bridge.

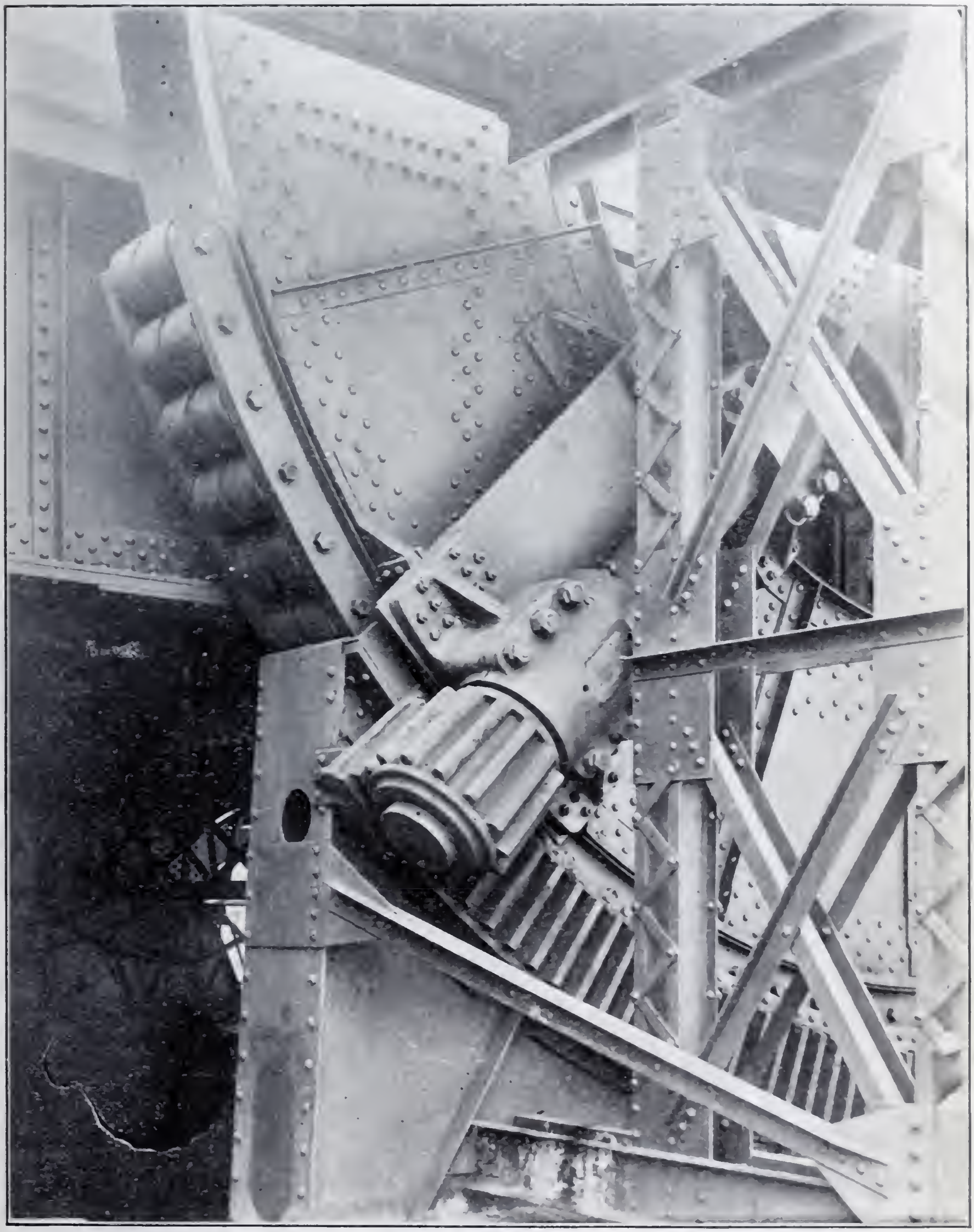

Fig. 26. Details of Cowing Bridge.

In 1891 a movable bridge known as the Weed Street Bridge was erected in Chicago of a type which may be termed a folding lift bridge, or a jack-knife bridge, as shown in Fig. 30. The bridge has two leaves each of which is in two parts, which are connected by a hinge. In opening, the outer portion of the leaf folds down on the inner portion as the latter rotates about a pin over the abutment. Each movable leaf is counterweighted and hung from a tower.

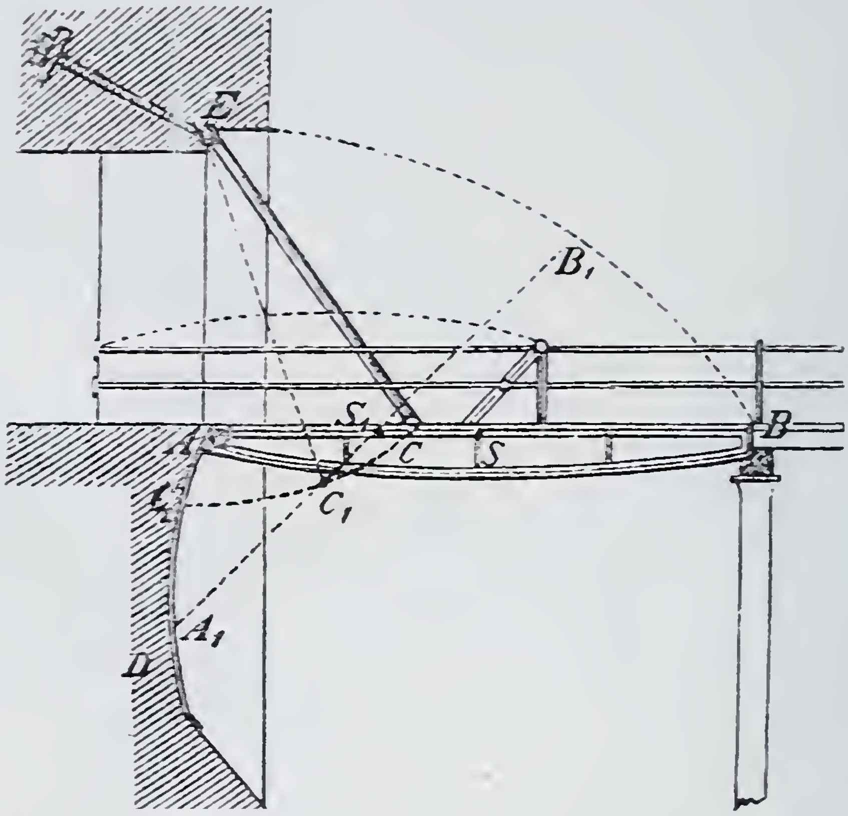

Fig. 27. Old Type of Lift Bridge, described by Hellenthal.

Hinged and rolling lift bridges, with two leaves, have been built, which when closed, act as arches. Most two leaf bridges, however, act as cantilevers counterbalanced by the counterweights and anchorages at the ends of the tail arms. Other bridges with two leaves have been designed to act as simple trusses between abutments, but as far as the speaker is aware, none have been built. The difficulty in constructing such a bridge would be in making a reliable, efficient and easily operated tension lock in the lower chord. In this regard, the Scherzer Rolling Lift Bridge Company and Mr. Strauss, of the Strauss Bascule and Concrete Bridge Company, have furnished the following information for use in this discussion:

From the Scherzer Company:

1. A number of our double leaf bridges have been built which act as arches.

2. No double leaf bridges have as yet been built to act as simple trusses. We control practical patents covering this construction, but so far the arch and the cantilever have proved to be more economical.

3. On double leaf bascule bridges acting as cantilevers a shear lock in the trusses is provided to take care of the deflection. It has been found that dove-tailing the ends of the

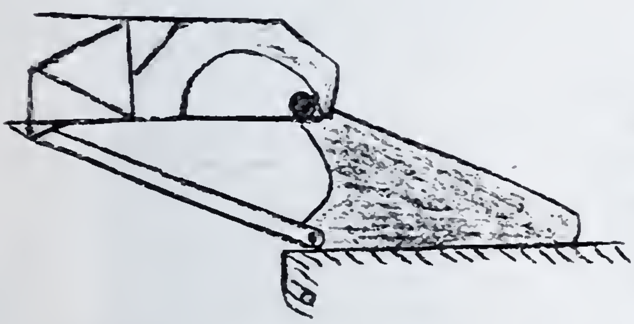

Fig. 28. A Schinke Type of Lift Bridge at Milwaukee, Wis.

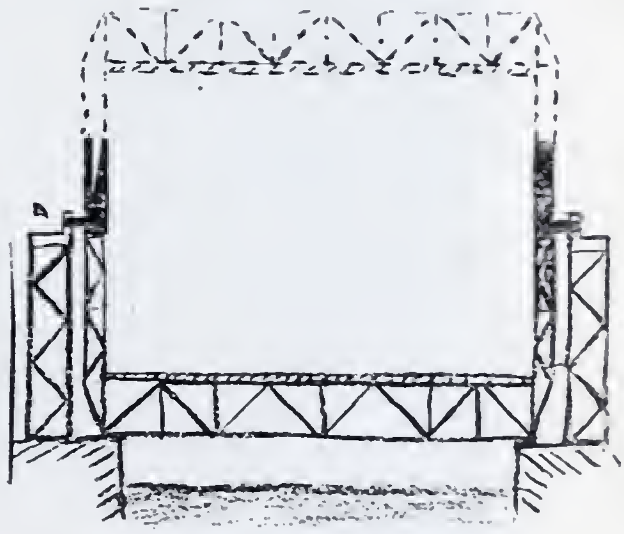

Fig. 29. Gyratory Lift Bridge.

Fig. 30. Folding Lift Bridge.

trusses into each other is more practical and efficient than a mechanically operated lock. Figure 31 shows one of these center locks when the bridge is being closed for traffic.

Fig. 31. Scherzer Shear Lock.

From Mr. J. B. Strauss:

1. The Knipels Bridge, at Copenhagen, is a double leaf bascule of my design, which acts as an arch when closed. This bridge will be completed this year.

2. We have designed a double leaf bridge with tension lock on the bottom chord under one of our recent patents, but have not built any.

3. In all our double leaf cantilever bridges we use a motor-driven shear lock.

A novel form of trunnion lift bridge with two leaves meet-

ing at the center was proposed and designed in December. 1891, by Mr. John N. Ostrom, of this Society, for spanning the Duluth Ship Canal. One of the striking features of this design is the folding bent supporting the free end of each leaf. These bents rested on a sunken pier at the center of the opening when the bridge was closed, and were lifted clear of the opening when the bridge was opened, leaving the channel unobstructed, as in Fig. 32. Another feature was the entire absence of counterweights. This lift bridge was not built, but some years later a ferry bridge was constructed.

It is an interesting question for discussion, "What should be the factor of stability for a closed bridge with two leaves which act as cantilevers?" Naturally the factor should vary

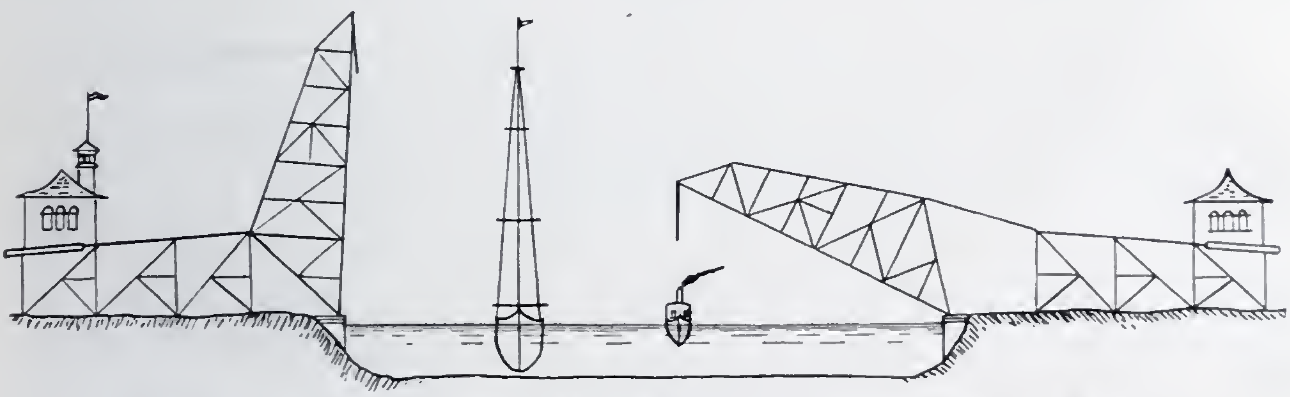

Fig. 32. Design proposed by John N. Ostrom for Bridging Duluth Ship Canal.

somewhat in different cases, but, in general, the speaker is of the opinion that such a structure should be designed to have a factor of stability of not less than two for the specified live load plus some allowance for possible future increase, combined with either the maximum longitudinal traction or an impact of not less than 25 per cent.

In determining the power required to operate a lift bridge, wind, snow, ice and water soaked and mud covered timber, are important matters which should be considered in addition to friction and the power necessary to overcome inertia. On occasion a bridge may be opened slowly and thus reduce the power required to overcome friction and inertia, but it is well to provide for emergencies by having some surplus power over ordinary requirements.

It is necessary for the operator of a lift bridge to have it

thoroughly under control as it nears the end of the opening and closing, to keep it from striking the tower and sub-structure. To accomplish this he has to contend with wind pressure as well as momentum. Important life bridges are usually provided with brakes, but it is a question whether it is well to rely solely on the skill of the operator. The way the Scherzer Company use the weight of the moving leaf in some of their bridges as a check to its momentum has already been mentioned.

Movable bridges, especially lift bridges, vary so much in type, general design and details, that the speaker, not wishing to consume too much time in opening the discussion, has confined his remarks to the prominent characteristics of the different types and to a few of the important questions which arise.

Mr. John Ericson:* In response to an inquiry from your Secretary, I beg to state that there are no difficulties encountered in the operation of Bascule Lift Bridges in Chicago, which could be ascribed to the influence of weather. All such bridges can be operated without trouble in any high wind during which navigation on the Chicago River is yet possible. The newer Bascule Lift Bridges, at least, can be worked against a wind of 70 or 80 miles per hour indicated velocity. During the high wind the operation takes, naturally, a little more time, perhaps as much as two minutes against the usual average of one minute needed for raising or lowering the leaves. The newer bridges are also provided with a double set of brakes so that if one of the brakes should fail the leaf still remains under control of another brake.

Occasionally a bridge gave a little trouble in hot weather when the river ends of the two leaves came too close together and a binding took place on account of expansion. Such faults can be easily overcome by shortening those ends, and if this is once well done no further trouble should be experienced, unless the abutment piers are too light and not strong enough to prevent crowding towards the river by pressure.

When I became City Engineer, in 1897, the rolling lift

* City Engineer, Chicago, Ills.

design was about the only one on the market in this country, at least in Chicago. I decided to take up the matter of a city design, and organized a force of able men for this purpose. The first result of our labors is described in the Annual Report of the Department of Public Works, for the year 1900, on pages 87 and seq. Since that time the city has constructed nine bridges on this design, and more are being added yearly.

In the Thirty-first Annual Report of the Department of Public Works of the City of Chicago, for the year ending December 31, 1906, on pages 268 to 284 is found an article in which the reasons are given for the preference of the trunnion bascule bridges, illustrated by diagrams and reproductions of actual photographs. The photograph showing the one leaf trunnion bascule bridge at Archer Avenue (Fig. 33), is the frontispiece in the report.

A variation on the city design, known as the Borg Bascule Bridge, is described in the Engineering Record of July 25, 1908, page 95, and is referred to and illustrated, Fig 19, in Mr. Prichard's discussion.

I give below a copy of some notes made in 1904 describing the principal features of the various types of bascule bridges used in the City of Chicago.

TRUNNION BRIDGE—CITY'S DESIGN

The bridges designed by the City of Chicago are bascule bridges with stationary horizontal axles or trunnions, similar to Fig. 13 in Mr. Prichard's discussion. The bridge forms a large see-saw of which one arm is the bridge leaf cantilevering out over the river and the other arm, the tail end, forms a lever with a heavy counterweight rigidly attached to balance the river arm.

As the available height for Chicago bridges is limited and as it would not be advisable to make the rear arm too short in proportion to the river arm, water tight pits are built to receive these rear arms and counterweights, when the bridge is raised.

The cut in the bridge floor dividing the fixed and movable parts is located on the river side of the trunnions; hence no

tail end locks are required to hold the leaf in place under any possible live load.

The bridges are operated by electric motors, the power of which, by a system of pinions and gears—gear trains—is transmitted to rack segments directly connected to the circular built tail ends of main trusses which act, so to say, as the first gear wheels.

It is an advantage of this type of bascule bridge that the main loads, through the stationary axles, always act at the same points on the foundations.

The system as such is not new, being in use already for many years in European cities. The center span of the Tower Bridge in London and the Fijinoord Bridge in Rotterdam are the largest European representatives of this type.

SCHERZER ROLLING LIFT BRIDGE

The Scherzer bridge (see Figs. 21 and 22 in Mr. Prichard's discussion), is also a bascule or see-saw bridge, but instead of turning around on a stationary axle it rolls on large, wheel-like, circular segment girders rigidly connected with the main trusses. Its axis of rotation moves horizontally and coincides with the centers of said circular segment girders. In this system, also, the river arm is balanced by a counterweighted rear arm.

The cut in the bridge floor dividing the stationary and movable parts is located in the rear (on the land side) of the axis of rotation. To prevent the bridge from rising under a load coming on the rear end of the movable roadway, tail end locks to support these rear ends become a necessary device in this type.

As the center of gravity of the movable bridge leaf must be close to the axis of rotation and this axis travels horizontally for a distance from 20 to 30 feet while raising or lowering the leaf, the foundation of this bridge must be built most substantial to withstand the detrimental action of such great shifting loads.

The operation of the bridge is usually done by operating struts pivoted to the main trusses and carrying racks which

Fig. 33. Bascule Bridge, Archer Avenue, Chicago.

mesh with pinions driven through gear trains by electric motors.

PAGE BRIDGE

As arranged for a deck span, the leaf of the Page Bridge turns around a stationary axle. The rear ends of the leaf trusses are very short and no counterweight is rigidly attached to them. They carry instead peculiarly formed tracks which support rollers attached to the river end of a movable, heavily loaded approach span. The other, or the land end of this approach span, is fixed to and able to turn around a horizontal stationary axle. This span, therefore, rests with one end on the stationary axle and with its other end, by means of said rollers, on the tracks of the short tail ends of the bridge leaf trusses, taking thus the place of counterweight and acting as such on the leaf trusses. During the operation the approach span sinks down at its river end, when the bridge leaf rises and vice versa.

The operation is done by operating struts actuated by screws and gearing, driven by electric motors.

By the arrangement of these short tail arms and of the approach spans forming the counterweight the necessity of tail pits is avoided.

On the other hand these movable approach spans require two additional breaks or cuts in floor over those needed in the city's design or in a Scherzer bridge.

In the Page Bascule Railroad Bridge, over the Chicago River, at Bridgeport, Chicago, which is a through span, the counterweight is carried in a swinging frame instead of utilizing the approach span. (See Fig. 18 of Mr. Prichard's discussion.).

Mr. George H. Norton* (by letter): In response to the inquiry from the Secretary of the Society I would say that we have experienced some difficulties in the operation of lift bridges owing to climatic conditions. We have in operation by the city one double-leaf bascule bridge, each leaf 76½ ft. in length; one Scherzer rolling lift, single leaf, 110 ft. long,

* Assistant Engineer, City of Buffalo, N. Y.

and one Brown design bascule bridge, single leaf, 166 ft. in length. The width of floor varies from 36 ft. to 46 ft. These bridges have power for operation against a wind pressure of from 3½ lb. to 5 lb. per sq. ft.

Our experience has been that the ordinary values of wind pressure accepted as being due to various velocities are very much overrated in action upon surfaces of these sizes. We have operated without material difficulty all of these spans in winds upward of 40 miles an hour.

The last mentioned bridge above is operated by hydraulic pressure in such manner that we could make a determination of wind pressures against the span and we hope to do so in the near future if possible.

In general, I would say that wind pressure has been of no serious moment to us in the operation of these structures at any time, as vessels cannot be operated in these narrow channels under wind velocities in which we can easily operate the bridges.

However, with the wood floors in use upon these bridges, the variation in moisture conditions and of snow load upon them, has given us some trouble.

The difference between new and wet planking and old dry planking puts us enough out of balance to at all times materially interfere with the ready operation of the structures.

In this climate we are also obliged to maintain a snow road across these bridges for the use of sleighs, and this snow load at times so overweights the span as to interfere with ready operation. For this purpose we intend to keep the bridges rather over-counterweighted.

In general, I would say change in balance due to moisture and snow are the governing features in the operating power required, rather than wind pressures.

Mr. Charles J. Poetsch (by letter): In response to the inquiry from the Secretary of the Society I submit the following:

We have nine lift bridges in operation in this city; six

* City Engineer, Milwaukee, Wis.

are of the fixed trunnion type; two are of the Schinke type, and one is a folding lift. The three latter are small bridges in comparison to the fixed trunnion bridges and represent the first efforts toward this style of construction of bridges in this city. The longest trunnion bridge is 130 ft. center to center of trunnions, is 60 ft. wide over all and has break in roadway 5 ft. in front of trunnion, thus giving a surface of 3,600 square feet for the wind to act upon. The rack in which main pinion engages is 7 ft. radius. The multiplication of power from motor to radius is about ninety. The motor is 50 H. P., 475 R. P. M. We have never experienced any difficulty in operating any of our bridges in high winds, although the effect of the wind is very noticeable on the power used. From information obtained from the Weather Bureau at Milwaukee and also from the experience with our bridges under all phases of weather, I would say that a bridge proportioned to resist 15 lb. per sq. ft. wind pressure was meeting all conditions of wind which might be imposed upon it.

Mr. Robert Hoffmann* (by letter): In response to the inquiry from the Secretary of the Society I beg to state that there are only two Lift Bridges in Cleveland under the control of the city. These are both double leaf highway bridges, one being of the Scherzer type and the other of the Cowing type. No trouble has been experienced in the operation of the same and I have heard of no complaints regarding difficulty in operating the same during high winds, but cannot state definitely that it has been necessary to operate bridges during what might be termed a gale. There are in this city six or seven railroad Lift Bridges of single leaf type, and as far as I know all are being operated successfully.

Mr. William Jackson† (by letter): In response to the inquiry from the Secretary of the Society I have to say that we have, operated by our city, seven Lift Bridges all over waterways of 36 ft. and under in clear width, and that, on account of their small sige, we have experienced no serious difficulty in operating them on account of high winds.

* Chief Engineer, City of Cleveland, Ohio.

† City Engineer, Boston, Mass.

Mr. Edward Godfrey:* For most conditions where a Lift Bridge is appropriate, there is nothing that is better than a plain trunnion bridge. The trunnion bridge is simple of construction and easy of operation. The friction is small, and the wear is almost negligible. The stresses are completely determinate, and the parts can be made in any well equipped shop.

There is no royalty to pay on such a bridge, and hence a large item of economy is already adjusted for the purchaser. There is no royalty to receive on such a bridge, and hence there is not the incentive to capitalize or push the construction of plain trunnion bridges. This accounts for the fact that plain trunnion bridges have not received the attention that they deserve.

In a trunnion bridge the mass is not moved along horizontally. This lessens the amount of work necessary to operate, as there is simply a rotation, in a well-balanced bridge, of a balanced mass. The friction on well-oiled trunnions is less than the rolling friction on a track that is of necessity imperfect and more or less rough. The inertia to overcome is very much less.

Another great advantage of the fixity of the dead load, is in the resultant stability of the foundation. A large mass moving back and forth on a pier is a very severe test of its stability and permanence; and the requisite mass of the masonry to maintain stability, as well as the reinforcement to maintain integrity, makes a pier properly designed for a bridge whose weight is transported in operating a very expensive piece of work. A pier that is not properly proportioned and reinforced will be racked by the moving back and forth by the great weight upon it. The evidence of this fault in bridges, whose mass is moved horizontally, or of the inadequacy of the piers, can be seen in some bridges already in use.

Rocking bridges crawl along on the track. This is a fault difficult to overcome. It is evidenced in bridges of this type in Chicago, and it gives rise to trouble. Teeth or bosses on the track do not hold the bridge; they rather break out metal

* Structural Engineer, Monongahela Bank Building, Pittsburgh, Pa. Read by the Secretary in the author's absence.

in the track. Still another fault in rocking bridges lies in the fact that the reaction, both dead and live, is in a single line, the line of contact between tread and track. Of course the compresion of the metal makes this line a surface of some extent. It also, as evidenced in the bridges, causes the metal to flow or crush. In a rocking bridge in Chicago, the angles on the segment broke on account of excessive wear, and when the bridge was opened, these angles remained on the track, being completely severed from the segment.

In another rocking bridge in Chicago, there is abundant evidence of excessive concentration of pressure on the segment, in sheared rivets, battered stiffeners, and crushed metal. Stiffeners at intervals do not adequately stiffen the tread of a rocker, unless the tread itself is very thick and rigid and the flange angles are very heavy, to carry the load to the web. Further, there is need of rivets enough to take the full reaction in close proximity to the application of that load. All of these features in proper proportion would demand very heavy and expensive construction. If, in addition, the girder or truss rocks on a plate or box girder, equally heavy construction would be demanded in the latter girder.

Trunnion bridges offer special advantages for double leaf spans, as the tail of the girder can be readily anchored and each leaf made a cantilever capable of independently supporting the live load. Sometimes the approach span is utilized to furnish part of the weight necessary to anchor the tail of the bascule girder. In single leaf spans the construction may be very much lighter than in double leaf spans, as the truss or girder is a simple free ended span for live loads.

The counterweight on trunnion bridges is preferably made of regular cast iron blocks with holes cored for bolts and the blocks securely bolted to the steel work. Sometimes concrete is used, but ordinary stone concrete would generally require too much bulk. A concrete can be made with steel punchings as the aggregate. This weighs about 300 lb. per cu. ft., which means about 45 per cent of the volume in steel.

Some excellent examples of fixed trunnion bridges are found in the City of Milwaukee. The first of these was built

at Grand Avenue in 1902. It is described in Engineering News, July 3, 1902, and in Engineering Record, July 12, 1902. The clear span on the center line of bridge is 95 ft. The length of each swinging girder from trunnion to end is 58 ft. 4 in. The width of roadway is 36 ft., and there are two sidewalks. The total width of bridge is 64 ft. and the total length including approaches is 180 ft. It has two electric railway tracks and was proportioned for a 55 000 lb. motor car on each track in addition to 100 lb. per sq. ft., covering the remainder of the floor. Each swinging girder is supported on a separate pier 16 by 32 ft. A load of 12 tons was allowed on each pile under these piers, and the piles are spaced so as to bring their center of gravity close to that of the weight of pier and steel work. The total weight of steel in the bridge, including approaches, is 855 560 lbs., and the cast iron counterweights weigh 690 180 lbs. The swinging girders alone weigh 260 580 lbs.

Another trunnion bridge at Broadway Street, Milwaukee, was completed in 1903. This bridge has a roadway of 36 ft. and is 56 ft. between handrails. It is 64 ft. 1 in. from each trunnion to center of bridge. The total length, including approaches, is 248 ft. 8 in. The four piers are each 26 by 16 ft. The clear span, when open, is 100 ft. It was designed for the same loading as the Grand Avenue bridge. Each leaf is operated by a 50 H. P. electric motor. The four main girders weigh 268 400 lbs. The steel work, including approaches, weighs 1 292 050 lbs., and the castiron counterweights weigh 900 860 lbs. A description of this bridge was published in Engineering News, July 14, 1904.

The Muskego Avenue bascule bridge is 53 ft. wide and 103 ft. 4 in. between trunnions. The West Water Street bascule bridge is 63 ft. wide and 103 ft. 10 in. between trunnions. Both of these are in Milwaukee.

The bascule girders of all four of the above named bridges rest on piers which have pits to receive the tail end of girder and the counterweight. At First Avenue and Sixth Street, Milwaukee, there are bascule spans in viaducts. These do not require pits for the counterweights. The City of Mil-

waukee is building another bascule bridge at Kinnickinnic Avenue, which is a tribute to the satisfactory working of this style of bridge.

MR. JOHN P. COWING* (by letter): In response to the inquiry from the Secretary of the Society, I submit the following:

Increasing channel requirements for the movement and handling of iron ore in the Cuyahoga River, Cleveland, are leading to the adoption of various expedients by the city toward facilitating the progress of the industry. Notable improvements in this line have been the elimination of a curve in the river channel at Jefferson street, which was very close to 300 degress, by cutting a channel between the two extreme ends of the curve, permitting the free passage of the largest boats drawing 20 feet of water, and the recent erection and opening to traffic of a new and modern Lift Bridge at this point, shown in Figs. 24, 25 and 26, in Mr. Prichard's discussion, which has supplanted a swing bridge.

The structure is the only example of its particular type in the city and is a two-leaf, revolving Lift Bridge, designed by John P. Cowing. The bridge has two 6 ft. sidewalks, its trusses are 40 ft. between front bearings, giving a clear waterway of 120 ft. at an angle of 12 degrees to the longitudinal axis of the bridge. The supporting end of the bridge is a semi-circular revolving segment having a bearing surface adapted to rest and roll on twenty-nine 10-inch anti-friction rollers 16½ in. long, which rest and roll in a cradle transmitting all the moving load uniformly to the foundation.

The motive power for operating the bridge is two 25 H. P. direct current electric motors for each leaf, one on each leaf being required for operating under ordinary conditions, while the other is held in reserve for emergencies. The power is transmitted to the main rack and pinion through a train of gears from a main equalizing gear on each leaf of the bridge. This latter gear takes the first reduction from the motor, thereby transmitting the same amount of power and motion

* Consulting Engineer, Hippodrome Building, Cleveland, Ohio.

to each of the two rolling segments of the main trusses of each leaf. To prevent lateral displacements, the rollers are recessed and held in alignment by distance bars composed of two channels.

The center of gravity of the moving leaf is at the center of a circular segment, the counterweight being partly above the floor and partly below it and consisting of pig iron set in Portland cement in a steel box with covering and riveted to each truss. There are some cast iron blocks below the floor for adjusting and properly balancing the bridge. When the bridge is closed, the dead and live load reactions are taken by a front bearing on the cradle. The uplift from the load upon that portion of the leaf which is between the center and the front bearing is taken by an anchor bar in the rear foundation and that portion between the center of the rolling segment and the abutment is taken by an electrically-operated tail lock. The total weight of steel in the bridge proper is 506 tons and in the counterweight 800 tons.

The bridge has the advantage, at all times, of keeping the dead load and the counterweight over the center of the pier, all resting and rolling on anti-friction rollers revolving in a cradle. The cantilever arms are counterweighted to be in equilibrium at all positions, and when lowered into position meet and lock at the center of the span with an automatic lock. Both arms of the bridge are controlled from one side, can be operated together or separately, are automatic in stopping at the extreme postions and in locking at the center, thus making it impossible for the operator, either by neglect or carelessness, to damage the bridge. The structure is designed to carry a street car track loaded with 80 000 lb. cars.

Mr. John L. Harrington* (by letter): In response to the inquiry from the Secretary of the Society, I submit the following:

The Halsted Street Lift Bridge, Fig. 7, in Mr. Prichard's discussion, which was constructed in accordance with Dr. Waddell's design some years since, is described in the Tran-

* Waddell & Harrington, Kansas City, Mo.

sactions of the American Society of Civil Engineers, January, 1895.

When the bridge was built the city authorities insisted upon the machinery being driven by steam engines instead of by electric motors, which Dr. Waddell planned to use. This not only added to the first cost, since it made necessary the construction of an expensive under-ground boiler room, but it increased the cost of operation because it is more expensive to keep up steam constantly for periodic use than to buy electric current from some large producer.

When the present City Bridge Engineer, Mr. Pihlfeldt, assumed control of the bridges belonging to the City of Chicago, the Halsted Street Lift Bridge received early attention, because the bridge had, on several occasions, failed in operation when the span was part way up. Examination disclosed the facts that at some much earlier period 26 tons of sand had been placed beneath the pavement to crown the surface, and the counterweights had not been increased correspondingly. Therefore, at each operation, the engines had not only to overcome friction and inertia, but to lift 26 tons of unbalanced load as well. It is not surprising, consequently, that the boilers would not furnish enough steam for operating two or more times in rapid succession, and that when the steam supply was exhausted the span had to remain wherever it happened to be, all or part way up, until more steam could be generated. Before this unbalanced load of sand was removed, it required both engines operating with 100 pounds steam pressure to lift the span, whereas, after the sand was removed but one engine with 40 pounds steam pressure was necessary. There have been no operating troubles since the sand was removed.

About two years since the steam plant was displaced by electric motors. Since then the cost of operation has been lower than that of most of the movable bridges and as low as that of any bridge in the city. The cost of maintaining the structure and machinery has been very low. The large amount of wire rope used has been thought to involve high maintenance charges, but that this idea is not well founded is

conclusively shown by the facts that the bridge has been operated about 3400 times a year for 14 years, that the original main cables are still in use, and that they are still in excellent condition.

Waddell & Harrington have recently designed two new types of Lift Bridges, one of which will be employed in the bridge over the Mississippi River at Keithsburg, Ill., for the Iowa Central Railway Company, and one for the Pennsylvania Lines West in the bridge over the Muskingum River in Ohio.

Another type will be used in a large Missouri River bridge. In this case not the whole bridge, but a deck supporting a double track railway, will be suspended from a fixed span and counterweighted at each panel point. The fixed span will carry electric railway, street and pedestrian traffic, and the hangers, which support the railway tracks, will rise through the main posts of the fixed span when the deck is lifted.

We have not exploited the Lift Bridge widely, but the economy it offers, the simplicity of design and operation, the long spans for which it may be employed, and the certainty of its action under traffic, make it a very desirable type of structure in our opinion, and in that of a number of railway engineers who have examined our latest designs. Tenders were taken on both the Lift Bridge and an ordinary draw bridge at Keithsburg, and the saving shown by the Lift Bridge amounted to $38 900.

Mr W. M. Hughes* (by letter): In response to the inquiry from the Secretary of the Society, would state that it has been the usual practice of the writer in the design of bascule bridges to use two motors, each of sufficient capacity to operate the bridge, the time for opening or closing, of course, being somewhat increased with one motor only in service, or with both motors running in series. To design the machinery with the usual safety factor for a load, say 50 per cent in excess of the output of H. P. for one motor to operate the bridge in a specified time. In this way the ex·

* Consulting Engineer, Postal Telegraph Building, Chicago, Ill.

cess power is ample to take care of any wind load, with a velocity not exceeding 35 or 40 miles per hour. With a wind velocity exceeding this, vessels are not likely to be moving, and consequently there would be no reason for operating the bridge.

In some observations made during the operation of the C. & A. R. R. bascule, shown in Fig. 18, of Mr. Prichard's discussion, with a wind velocity somewhat exceeding 30 miles the ampere readings seem to indicate very little additional power required due to wind pressure for this velocity. With the closed floor of a wide highway bridge the effect would, no doubt, be somewhat greater.

Relative to the snow load, there is, of course, no necessity for any provision being made for a railroad bridge where the floor is open. In the case of a highway bridge, this is seldom, if ever, loaded to the full capacity for which it is designed; further, the snow load being only temporary, the usual margin for safety should be ample to take care of this.

The selection of the single or double leaf design depends largely upon local conditions. Ordinarily the single leaf is the more economical for the same clear opening, particularly for railroad bridges. For highway bridges the double leaf has the advantage in the most of types of bascule of blocking the opening on both sides of the waterway. Ordinarily, I would consider it desirable to design the double leaf bascule as cantilevers, with suitable provision to transmit a portion of the live load from one leaf to the other, the amount depending upon the nature of the traffic.

Mr. Albert Lucius* (by letter): In response to the inquiry from the Secretary of the Society, I beg to say that since I do not know the scope and purpose of the discussion and do not know whether there is any definite proposition before the Society to be discussed, I can only offer my views generally, namely that for railroad purposes, my preference would be in favor of some form of rolling Lift Bridges with the counterweight immutably connected with the bridge struc-

* Consulting Engineer, Potter Building, New York, N. Y.

ture, and that simplicity of detail and facility to manufacture with precision is the main consideration in applying this "rolling" principle, and final types will develop along these lines.

There is, however, a large field for hinged types of bridges which turn on a shaft or trunnion, and which lend themselves to a great variety of design and location, and which will be generally more economical for lighter constructions, especially if the counterweight is connected to the bridge structure by means of flexible members or ropes in such a manner that it relieves the bridge weight at the hinge point and the distribution of the total weight is effected over several supports instead of being concentrated at the hinge, or if the counterbalancing is effected by hydraulic accumulation. Much opportunity is given to the display of ingenuity of the designer in developing proper combinations of bridge structure and counterweight and the application of the driving machinery.

Mr. Charles L. Strobel* (by letter): In response to the inquiry from the Secretary of the Society, the writer advises with regard to Mr. Prichard's question, "What should be the factor of stability for a closed bridge with two leaves which act as cantilevers?" He is in agreement with him, that is to say, a factor of stability of two, subject to the restriction he mentions, would, in the writer's opinion, be adequate.

Mr. J. B. Strauss:† I will confine my remarks to a very short discussion. Mr. Prichard's paper illustrates the ingenuity of the engineer in bridge design. It is a question whether all these designers really obtained the object they sought. I think the tendency today is toward development of a design which will eliminate every uncertain element, such as flexible connections, ropes, chains, adjustable counterweights and other features which are not definite, positive and rigid. I think that might be taken as the key note of bascule bridge design. The reason for this is evident to anyone who has had the maintenance of bascule bridges under his charge. The bridge which has the least parts to get out of order, whose

* President, Strobel Steel Construction Co., Chicago, Ill.

† President, Strauss Bascule and Concrete Bridge Co., Chicago, Ill.

members do not change their relative position and strength, which is not easily deranged by external influences and which has no parts subject to excessive wear and deterioration, is the bridge which will prove the cheapest and the best and most effective in service.

The single leaf bascule bridge is always preferable to the double leaf, for the reason that it is a simple span when closed, has no uplift and has but one set of machinery. The double leaf, when designed as a simple span, approximates closely to the single leaf, since the uplift is also eliminated and the form of center lock necessary insures great rigidity. The development of such a center lock, however, has proven to be the stumbling block and it is only recently that we have been enabled to hit upon a design which seems promising, and which I trust we will have an opportunity to apply in practice in the very near future.

Most double leaf bascule bridges have been designed on the cantilever principle, which is quite satisfactory for highway bridges. The anchorage is always more than sufficient to take care of maximum variations, and in most cases the effect of one leaf on the other is also figured in, the transmission being effected by the shear lock. Some double leaf bridges have been designed and built as three-hinged arches, which makes a somewhat stiffer bridge and is economical where foundation conditions are satisfactory. The only large modern structure of this kind is our bridge at Copenhagen. Denmark, just completed.

We make no special provision for snowload and water-soaked timbers. The machinery is proportioned for a certain assumed friction and condition of balance, and for a prescribed wind resistance. Any and all of these may vary, and snow and rain are some of the contributary causes of these variations. The variation merely effects the speed of operation and is fully provided for by the usual specifications, which impose a certain nominal speed under ordinary wind loads and a reduced speed for higher wind loads.

That is about all I can say as to the general theme, except to answer further the question of Mr. Prichard relative to

Fig. 34. Strauss Bascule Bridge, Kinzie Street, Chicago.

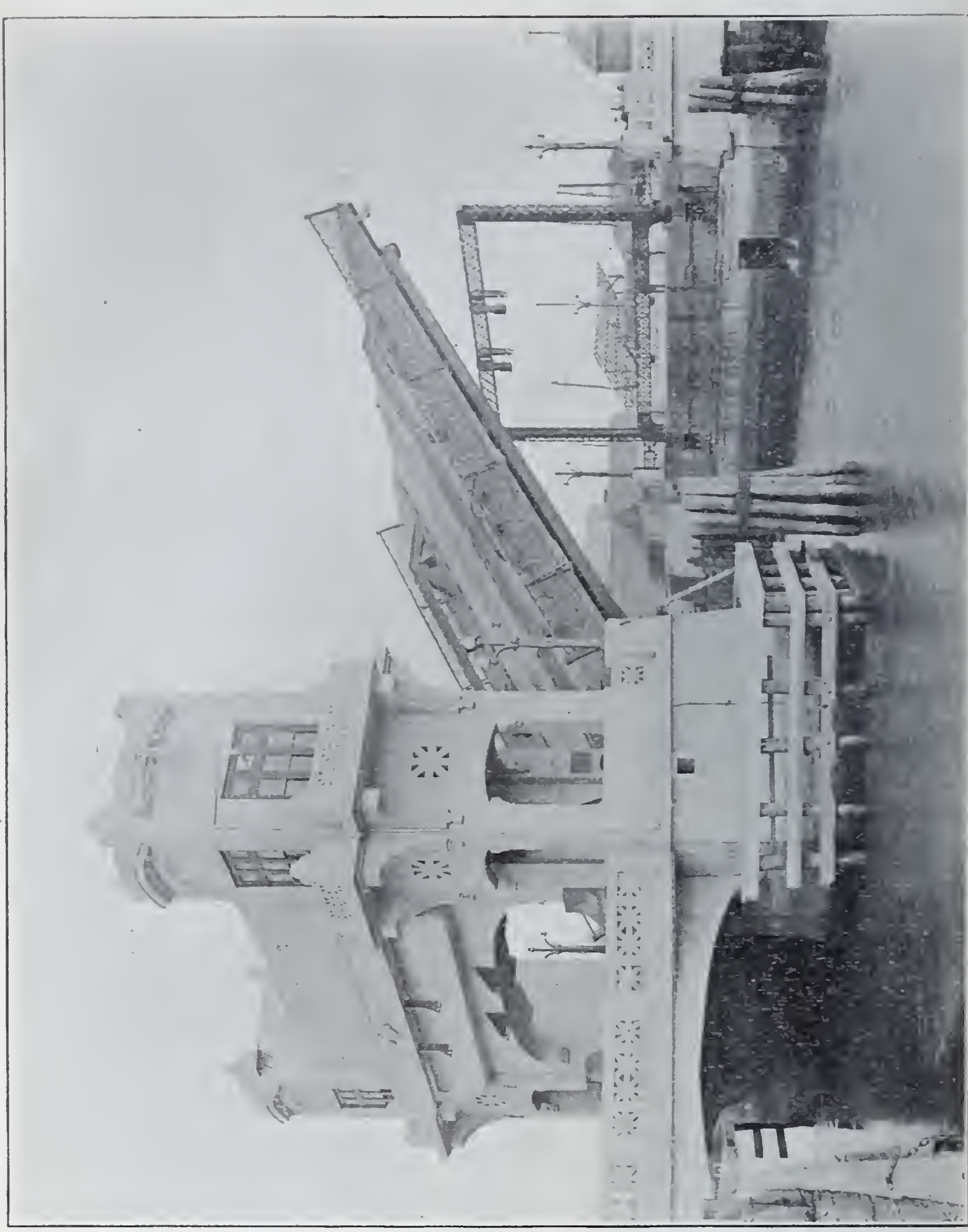

Fig. 35. Strauss Bascule Bridge, Federal Street, Camden, N. J.

the shear lock for two-leaf cantilever bridges. We have found that a positive connection between the two leaves is desirable to insure rigidity. The Scherzer type of lock may be effective as far as it goes. But the same reason which is responsible for the use of a single leaf bascule wherever possible is also responsible for the selection of a permanent and definite connection between the two leaves, where you have two. The practice in the Chicago and Milwaukee bridges is to use a

power driven lock, and we have followed that practice, because it appears best.

The slides, which I will show, will illustrate better than any remarks I can make, the fundamental features of our design and some of the old types.

Our bridges, including some recent types, are also shown in Figs. 16 and 17 of Mr. Prichard's discussion and photographs, Figs. 34 and 35 which I submit.

Mr. H. S. Prichard: What is the practice in regard to the stability of double leaf bascule bridges in designing the anchorage, how close to the wind do you sail?

Mr. J. B. Strauss: We figure fairly close, using the average factor of safety used in the rest of the structure. As a matter of fact, the anchorage is made a little heavier than the maximum loads you get on the bridge, and it generally proves possible to do this without any great sacrifice.

Mr. H. S. Prichard: If the live load over the bridge should double what would happen to most of the bridges?

Mr. J. B. Strauss: I do not believe in most of the cases it would affect them. In some of the smaller bridges it might but in most of the heavier structures I think the anchorage is more than sufficient to take care of the uplift, for the reason that the loads on the structure itself usually assist in resisting the uplift. Still this is one of the reasons why a double leaf bridge is not as desirable as a single leaf. In a single leaf you get what I would call the ideal construction; it eliminates every element of uncertainty. It is superior even to the swing bridge for that reason. The swing bridge has an element of uncertainty in the end locks for the leaf and the track. In the single leaf bascule, these are absent, and if the design is of the proper type, so are all other uncertain elements.

Mr. J. T. Dickerson:* While I am more or less familiar with the various types of lift bridges described by Mr. Prichard, I believe that one of these types in itself approximates the ideal lift bridge; because it secures the best results with

* Assistant Engineer, The Scherzer Rolling Lift Bridge Co., Chicago, Ill.

the least expenditure. An analysis of the Rolling Lift Bridge will show that it is the most economical in first cost, in operation and maintenance.

It is most economical in first cost, because for a given clear navigable channel it requires the minimum movable span between bearings, due to the fact that in opening, it rolls back and away from the navigable channel. Most trunnion bridges are so constructed that, in opening, a part of the bridge revolves around in front of the bearing, thus necessitating the placing of that bearing a considerable distance back of the channel, with a resultant increase in movable span, stresses, sections, counterweight, machinery and sub-structure.

The Rolling Lift Bridge is the most economical to operate, because in it friction is reduced to a minimum. Large rollers on smooth level tracks provide the most perfect mechanical construction known for the reduction of friction. Trunnion bridges and vertical lift bridges, where great weights are carried on pins, axles, journals, etc., in operating, involve the sliding of metallic surfaces upon each other under enormous pressure, thus necessitating a large expenditure of power and increased weight of machinery.

The Rolling Lift Bridge is the most economical bridge to maintain, because it has the minimum number of parts. The moving leaf is practically one piece from end to end, and is without links, pins, cables, trunnions, etc., all of which are elements liable to disorder. Some trunnion bridges have a counterweight suspended by pins, links or other flexible connections, thus depriving the main trusses of bracing where it is most essential, and as a rule, when these bridges are operated, this suspended counterweight sweeps between the trusses cutting out other bracing. A close study of many types of trunnion bridges will show that they are seriously lacking in bracing, and this lack of bracing and non-rigidity of structure is liable to result in a gradual racking of the entire bridge, and a consequent increased expenditure for maintenance. With the Scherzer Rolling Lift Bridge, however, the concrete counterweight is encased in a steel box reaching across from truss

to truss, and rigidly attached thereto, thus forming the most substantial kind of bracing.

The first bridge of the Scherzer type was constructed by the Metropolitan West Side Elevated Railway Company across the South Branch of the Chicago River, and has been in continuous service for over thirteen years. This bridge is a double leaf four-track structure, consisting of two double-track bridges side by side. It carries over 1200 trains daily and has been operated over 1,000 times a month. The maintenance charges for this bridge, aside from painting, have been practically nothing.

On a few of the early bridges some of the bolts fastening the curved track plates to the outstanding legs of the segmental girder lower flange angles were spaced too far apart and on this account were over strained. These bolts were ⅞ in. diameter spaced from 12 in. to 16 in. centers. These bolts were easily replaced at slight expenditure and the efficiency of the bridge was in no way impaired, but on later bridges rivets or bolts have been used for this fastening, spaced more closely, thus eliminating any difficulty from this source. There are now many bridges carrying rolling loads 100 per cent greater than the early bridges, and these larger bridges have been subjected to the most severe operating and traffic conditions over many years and do not show the slightest movement of track plates or failure of rivets attaching the same.

Fig. 36 shows a bridge constructed by the New York, Chicago & St. Louis Railroad Company over the Cuyahoga River at Cleveland, Ohio. This bridge is a double-track railway structure having a movable span of 160 ft. between bearings and is designed for Cooper's *E* 50 loading. It is operated by two 50 H. P. motors, which, with the machinery, are mounted on the movable leaf. These motors through a simple series of gearing deliver their power into two main operating pinions; the shafts of which pass through the main posts of each truss and carry spur wheels at their outer ends which engage the fixed racks, of which there are two; one on each side of the track girder span. These operating pinions, being at the center of roll, move in a straight horizontal line, and this center of roll

is also the center of gravity of the bridge; the bridge being balanced in all positions. The accompanying cuts show a few of the different types of Scherzer Rolling Lift Bridges, and illustrate their wide adaptability. (See Figs. 36 and 37).

In the ordinary double leaf bridge the rear end of each leaf is anchored and the leaf acts as a cantilever. Several double leaf Scherzer Rolling Lift Bridges, however, have been constructed as three hinge arch bridges, thus rendering the anchorages unnecessary. Double leaf Scherzer Rolling Lift Bridges have a shear lock at the center, which is capable of transmitting shears from each leaf to the other. This shear lock, Fig. 31, of Mr. Prichard's discussion, is a part of the structure, is fixed and has no moving parts. It consists of two or more pairs of jaws riveted to the end of one leaf and of two or more tongues riveted to the end of the other. In closing the bridge the tongues move in between the jaws, thus forming a simple and positive lock. Fig 31 shows the center break in floor of the double-deck highway Scherzer Rolling Lift Bridge across the Taunton Great River at Fall River, Massachusetts, also shows the Scherzer shear lock. In this case the jaws and tongues are each simply a continuation of one of the main girders of the bridge, there being two girders to each leaf or four in all.

Electricity is the most satisfactory power for operating bascule bridges and it is most generally used. Gasoline power ranks second and is used on a number of bridges where electric power is unavailable. Steam power has been used on a number of bridges, but with the marked development in gasoline engine design within the last few years steam has been largely superseded by gasoline. Hydraulic power has also been used.

Mr. Ericson, in his discussion, gives some notes made by him in 1904, describing the various types of bascule bridges used in the City of Chicago. The City of Chicago has built but two Scherzer Rolling Lift Bridges. As more than 90 have been constructed since 1904, Mr. Ericson's notes regarding this type of bridge are out of date.

Mr. Godfrey, in his letter of discussion, stated that nothing is better than a plain trunnion bridge. It would seem from

Fig. 36. Scherzer Rolling Lift Bridge, N. Y. C. & St. L. R. R., Cleveland, Ohio.

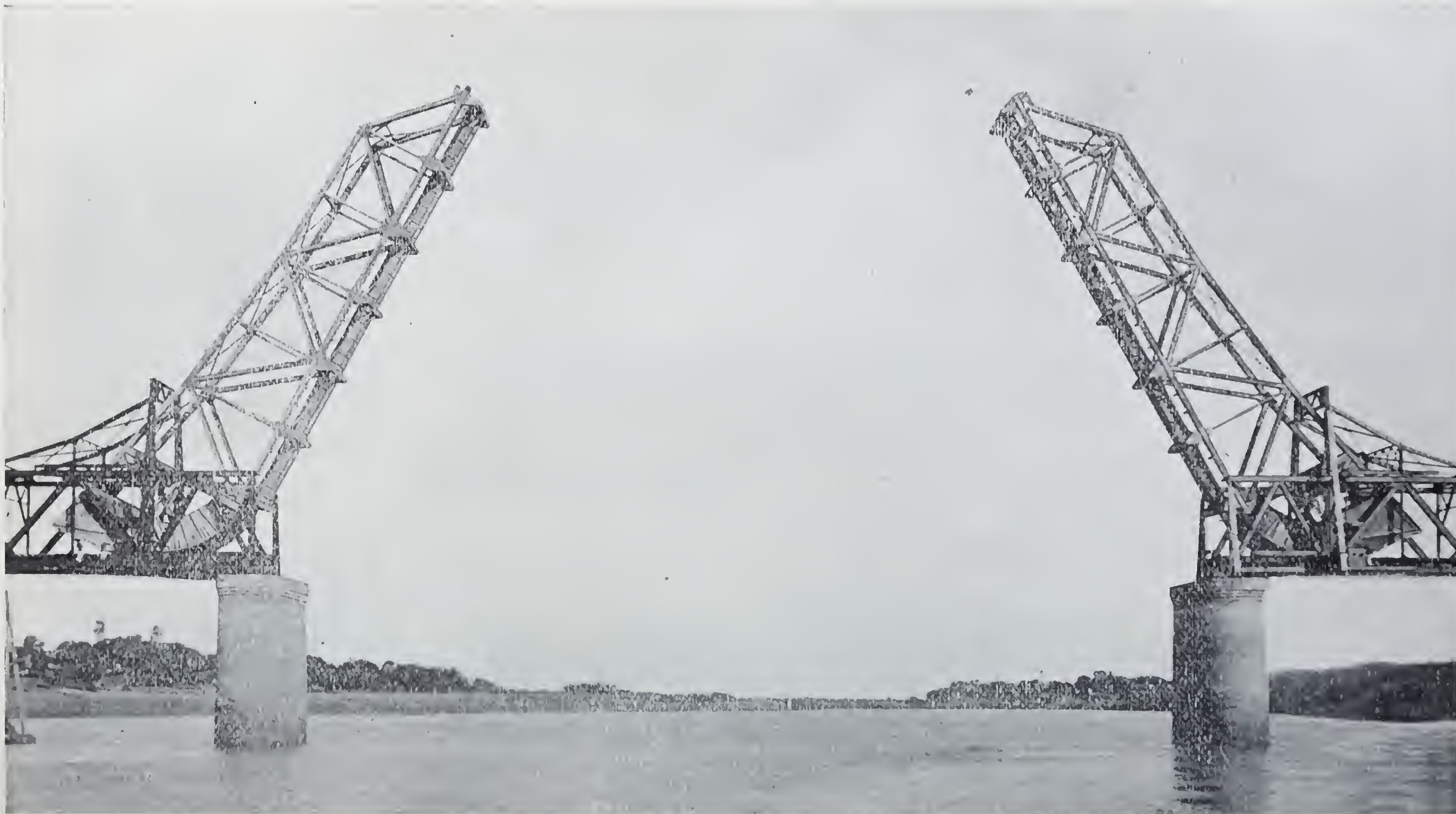

Fig. 37. Scherzer Rolling Lift Bridge, 220 ft. span. For Burma Railways Co., Rangoon, India.

some of his other statements that he has not kept in touch with the great progress and development that have been made in the design of bascule bridges of the Rolling Lift Bridge type since its invention, during the past 15 years. The trunnion bridge is more expensive than the Rolling Lift Bridge:

First. Because the movable span must be longer.

Second. Because, due to the limitations of the trunnion bridge, the counterweight must be of cast iron or other heavy and expensive materials; the first factor adding from 10 to 25 per cent to the cost of the bridge, and the second factor from 10 to 20 per cent to the cost.

It may be true that the plain trunnion bridge has merits over the modified trunnion types which have a multiplicity of trunnions, links, etc.

The track of the Scherzer Rolling Lift Bridge is neither imperfect nor rough, and the Rolling Lift Bridge does not roll upon the piers. It moves upon a track girder which is supported upon the piers or upon a fixed approach span. Contrary to what Mr. Godfrey, in his discussion, seems to suppose, the track girder is not usually supported throughout its length on the masonry, but only at the ends where it rests on steel bolsters embedded in the masonry, and in this respect it does not differ from the usual type of plate girder construction. This type of construction does not involve any so-called "rolling on the masonry," for reactions from the rolling bridge are entirely vertical and are of the same nature as the live load reactions, and the piers are designed on the same basis as the piers for any bridge. Bridge piers are primarily built to carry moving loads.

The Scherzer Rolling Lift Bridge Company charges no royalties. Its charges are for consulting engineering services in the preparation of designs, plans and specifications, supervision, etc., and are based upon the amount of work and responsibility involved.

To examine the other questions raised by Mr. Godfrey would make this discussion too extended.

It has added to the prestige of American engineers, and it may be interesting and gratifying to know that the geograph-

ical distribution of the one hundred or more lift bridges of the Scherzer type which have been built or are under construction, include besides our own country, Canada and Mexico, Argentine, Great Britain and Ireland, Holland, Russia, India, Egypt and other countries. Among these bascule bridges are to be found the longest span, the widest and many of the most actively used.

Mr. E. W. Pittman:* The essential features of the Brown Bascule Bridge, so called from the name of the patentee, Mr. Thomas E. Brown, are shown in Fig. 12 of Mr. Prichard's discussion. A bridge of this type was completed about a year ago for the City of Buffalo. It is on the line of Ohio Street and spans the Buffalo River.

The most noteworthy feature of this bridge is the manner of counterbalancing, and the method of operating the lift. The movable arm of the bridge is counterbalanced by cast-iron weights suspended from cables passing over 10-foot sheaves at the top of the tower. These cables are wrapped around a balancing curve and attached to trusses at a panel point of the bottom chord. This balancing curve is so designed that the counterweight exactly balances the movable arm in every position from level to 81 degrees; that is to say, the movement about the trunnion pin of the arm is, in any position, equal and opposite to that of the constant stress in the cables about the same point. The accurate determination of the balancing curve was a very tedious process. No direct equation could be derived for the curve, and hence it was necessary to determine numerous points on it by computing lever arms of cables for various corresponding positions of bridge. Points thus determined were revolved into the same relative position and joined by the required curve. This process was complicated somewhat by the continually changing position of the trunnion. It will be seen from the diagram that the trunnion moves in the arc of a circle, whose center is the pin in the rear end of the connecting strut.

In order that the movable arm may not be thrown back

* Chief Engineer, Pittsburgh Steel Construction Co., Pittsburgh, Pa.

against the tower, there is a reverse curve around which the cables wrap when the arm passes 81 degrees. To move the arm beyond this point, continually increasing power is required, and the full power of the machinery is required to move the arm to the 90 degree position. This device renders the structure safe against careless operation and high wind pressure.

The movement of the bridge is actuated by horizontal pressure applied at the heels of the trusses below the trunnion. The machinery consists of two steam pumps, which maintain pressure in water tanks. This water, under pressure, is conveyed to a hydraulic cylinder at the heel of each truss. The control is through a set of valves by means of which the water is led simultaneously to the two cylinders, and to the front or rear of the piston head, according as is desired to raise or lower the bridge.

A complete description of this bridge, with numerous diagrams, is given in Engineering News, January 16, 1908.

Mr. John N. Ostrom:* Mr. Prichard suggested that I discuss my design for the Duluth Ship Canal Draw Bridge competition of 1891 and without further introduction let me read from Engineering News of February 20, 1892, the salient points in the competition, as described in a circular issued to competitors:

"Competitors will be required to make their own investigations for plans and specifications; also to state the time required to open and close the draw during the most unfavorable weather, and the time required to complete the whole work. The present width of the canal is 250 ft., which is not to be diminished.

"The bridge is to be 48 ft. in width over all and must accommodate one railroad track, two highways and two sidewalks. The bridge must be proportioned to carry, in addition to its own weight, a moving load composed of two consolidated 86-ton engines, followed by a train load of 3000 lbs. per lineal foot, a highway loading of two connected electric

* Bridge Engineer, Farmers' Bank Building, Pittsburgh, Pa.

motors, each weighing 15 tons when loaded, for each roadway, followed by a moving load of 500 lbs. per lineal foot for the entire length of the roadways, with special provisions for extreme wheel loads affecting the stringers, and a sidewalk loading of 100 lbs. per square foot of surface. Under this loading the strains are to be proportioned for the quality of steel used, varying from 10 000 lbs. per square inch for all live loads to 20 000 lbs. per square inch for all dead loads.

"Soft steel to be used, 62 000 to 68 000 lbs. ultimate strength with 36 000 lbs. per square inch elastic limit.

"Competitors are cautioned that the term 'Drawbridge,' herein used refers to a drawbridge proper, or one that will draw back and leave the canal open and free for its entire width, and that plans submitted for a swing bridge will not be considered.

"Following are some of the principal conditions of the location: The present roadway is 7 ft. above mean water level; the bridge to be 10 ft. above same. Height of quiet water varies about 2 ft. The swell runs to about 5 ft., and the water is from 25 to 32 ft. deep. There is usually a strong irregular current. The material under bottom of canal is fine sand. There is no means of shutting off the water. In spring and summer the canal is often obstructed by rafts."

There were 16 designs submitted. The following brief synopsis of the designs is an abstract from the Duluth Tribune of December 29, 1891:

"Mr. J. A. L. Waddell, of Kansas City, submitted a plan that, while not conforming to conditions, drew out many favorable comments. He submitted another plan, however, meeting the conditions with false approaches at each end sliding sideways, with the main bridge separating in the middle and sliding back into the vacated approach pockets. Cost, including approaches, $154 000. Mr. Waddell's plan No. 1 provided for two towers furnished with 15 ft. built steel pulleys, arranged to lift the bridge vertically by aid of counterweights; cost $105 000, with no land needed for special approaches.

"Messrs. Oscar Sanne and W. H. Finley, of Milwaukee, submitted plans for a double draw to cost $140 000.

"Mr. W. L. Stebbings, engineer of the Chicago & North-

western Railroad, proposed a pontoon and a lift bridge to cost $18 000.

"Mr. F. C. H. Arentz, of Milwaukee, submitted a plan for a single draw, to cost $300 000. Mr. H. Breen, of Chicago, proposed a draw operated by rollers on the bottom of the canal to cost $160 000. Mr. John N. Ostrom, New York, had a plan for a double lift with a pier midway in the bottom of the canal, on which rested hinged supports for the free end of the bridge when closed. The Strom-Lindman-Hilliker Tunnel Company of Minneapolis, submitted a tunnel design to cost $500 000 for a double canal. Mr. William Sooy Smith, of New York, designed a double draw, rolling back, for $221 000. Mr. E. B. Jennings, of Springfield, Mass., had a plan for a double swing bridge to cost $17 000. The prize of $1000 was finally awarded to Messrs. Arentz & Sangahal, of Milwaukee, for a pull-back drawbridge, which is apparently not included among those described by the Tribune."

Let me call your attention to the fact that this was probably the first case of modern engineering where the old form of so-called draw bridge did not fit, and in fact it was excluded from the competition. I refer to the well known swing bridge. Why this form of bridge was ever called a draw bridge is a matter of ancient history, which is not at all important, but which would be highly interesting if any authentic records could be unearthed to describe the evolution.

As the special bridge desired must be located on a busy city street where houses were built on the street line clear up to the canal, both sides, the swing bridge was impossible, since the arms could not have been swung to open the draw without hitting the buildings on the street.

The City Fathers proposed a bridge that would draw back longitudinally in the street, and were blind to a much better form which has now come into quite general use. I refer to the drawbridge of medieval times, which spanned the moat and which could be drawn up and lowered at will from the castle wall.

At the time of the competition I was not busy, and as the subject was interesting I went into it at length. Since it is

always good business to please the average commissioner or engineer by conforming strictly to his letter of invitation, I naturally took up the draw back bridge and made two complete studies of same; one a counterbalanced arm of 250 ft. spanning the entire canal, and the other two arms of 125 ft. each. In both cases the street had to be obstructed by one or two pits, which were ugly if left open and difficult to cover with platforms if required bridged when ready for traffic. Either plan was entirely practicable, since it was comparatively easy to roll back longitudinally plan No. 1, 250 ft. in one direction in the street, or plan No. 2, 125 ft. in opposite directions. The latter plan was the better of the two, since it halved the time of operation, but both seemed clumsy and inappropriate to me.

The idea of the old medieval draw had occurred to me at the outset, and owing to comparative youth and inexperience, I decided to brave the displeasure of the Commissioners by presenting a plan not asked for and not then in the text books. It worked out to my entire satisfaction at that time, and I therefore present it to your attention this evening. In doing so I wish it to be distinctly understood that I make the exhibition simply as a matter of ancient history, in the hope that it may be of interest, since to the best of my knowledge, it was the pioneer modern design of the ancient castle drawbridge.

And here and now let me refer to Engineering News of October 27, 1892, p. 390, which gives a fair and impartial description of the various designs presented with a good inset illustrating each.

As will be seen at a glance from the inset, similar to Fig. 31, in Mr. Prichard's discussion, my design was the only one presented having the uplift principle, which is common today, and I suppose it might be called a trunnion draw, although the absence of counterweight prevents the term from being strictly applicable. For further description I quote from Engineering News as mentioned above:

"The design presented by John N. Ostrom, of New York City, for which Mr. Thomas E. Brown, Jr., of New York City,

designed the hydraulic lifting machinery, was a double lift draw, consisting of two channel arms, each 127 ft. long c. to c. of bearings, and two shore arms each 95 ft. 3 in. long c. to c. of bearings. It provides for a roadway of 20 ft. wide, carrying two electric street car tracks and the general street traffic, one single track steam railway, 14 ft. clear width, and two sidewalks, each 5 ft. wide. Each channel arm is supported at the abutments by a hinge and at the center of the canal by swinging piers resting in sockets in a pedestal in the canal bed. The shore arms support the hydraulic machinery for operating the draw. To open the draw each channel arm revolving on the abutment hinge is drawn backward and upward by hydraulic cylinders operating through the common method of a connecting rod and working beam. When released the arms descend by gravity; the rate of movement being controlled by the hydraulic cylinders.

"As will be seen, a very important part of the bridge is the hydraulic machinery for its operation. In brief, this consists of two sets of three hydraulic cylinders and air accumulators, and one set of boilers, pumps and the necessary appurtenances to operate both sets of cylinders. One set of cylinders is placed on the top of the shore arm on each side of the canal and the pistons of each set are connected to a traveling girder, which in turn is connected with the working beams attached to the channel arm of the bridge. Power is supplied by two 50 H. P. boilers operating two Worthington duplex pumps; one to operate each arm, and so arranged that the power of both may be combined to operate one arm in case of necessity.

"With this machinery the arms of the draw can be operated separately or together; the time required to open or close the draw being from 1½ to 3 minutes. The operating force consists of an engineer and fireman.

"The advantages claimed by the designer of this bridge are: rapidity of action; simplicity of design; adaptation for variable heights in vessels; economy in operation and the avoiding of false work in construction. Its cost was estimated at $125 000."

You will observe that I was associated in this competition with Mr. Thomas E. Brown, Jr., of New York City, who was at that time engineer for the Otis Elevator Company. My idea was to get the very best motive power, and hydraulic power seemed to me the most suitable and practicable at time. Since Mr. Brown had designed the hydraulic machinery for the elevators of the Eiffel Tower for the Paris Exposition of 1889, he was enabled to use the old patterns, and adapt the old machinery to the proposed draw to good advantage, and this reduced the estimate for the machinery to a minimum.

Since I am presenting this as a novel design, outside of the field of competition, let me call your attention to perhaps the most striking feature. I refer to the swinging bent supporting the free end of each arm of draw. Since I desired to entirely cut out counterweight and make arms of draw as light as possible I hit upon the device of the swinging bent. This feature is illustrated on blue prints 1, 2 and 5 of my plans, and now I submit the whole set, 1 to 8 inclusive, for your examination. As will be seen the bents were supported on a sunken pier in the center of the channel flush with the bottom. Since the channel's bed was sand with a quite strong current running, silt would not have collected at the bottom, and indeed the local tendency was to scour and not to fill as reported to me at the bridge site.

Although this feature was not favorably considered by the commissioners, and, as far as I know has never been used since, I still believe it to be entirely practicable. If used as a part of a so-called trunnion draw with counterweight, and modern operating machinery, it certainly would reduce dead weight, and therefore total cost.

Before closing let me call attention to wind pressure. I found this the most serious problem when it came to operating the bridge, for since vesels must come in on high winds it seemed necessary to open the bridge to its full height and hold it against the wind. I finally decided to provide for a wind pressure of 30 lbs. per square foot on the uplifted arms of the draw, the wind blowing longitudinally to the bridge and therefore striking an exposed surface of 48 ft. width by 125 ft.

height. You will at once realize the power required, but it was amply provided for by the hydraulic machinery as designed.

A few weeks ago I had a short chat with an engineer who told me that he was designing a double lift draw with 250 ft. uplift. When I stated that it seemed to me a pretty big proposition to uplift the arm of a draw 250 ft. in a stiff wind, he very promptly stated that he did not provide for it, and did not propose to open the bridge under such circumstances. This certainly reduces the problem of uplift to comparatively simple figures; but when a boat seeks a harbor of refuge in a gale, and the draw is closed, something is going to happen not provided for in the plans and text books.

[The Scherzer Rolling Lift Bridge Company prepared a statement in reply to the Thirty-first Annual Report of the Department of Public Works of the City of Chicago, referred to in Mr. Ericson's discussion. Mr. Dickerson, Assistant Engineer of the Scherzer Company, likewise furnished a further reply to the above report. Both of these replies, together with the Twenty-fifth and Thirty-first Annual Reports of Department of Public Works of the City of Chicago, are in the archives of the Society.—EDITOR.]

SECONDARY STRESSES IN FRAMED STRUCTURES

By E. W. Pittman.*

Secondary stresses in framed structures are due, primarily, to faulty details. Attention will be directed to some of the more common faults and inconsistencies that are of frequent occurrence in structural details, and an effort made to illustrate their effects upon the strength of the structures.

In the general design of an articulated structure, such as a bridge or roof truss, it is assumed that the axes of the various members meeting at a joint are concurrent; that is, intersecting at a common point, and that they are free to rotate about this point as elastic deformation takes place.

In the case of a pin connected truss, the assumed conditions are very nearly realized, but in the case of a riveted truss, the last condition is not fulfilled. The riveted joint fixes the direction of the members at their ends, and when the structure deflects under a load, all members are placed in double curvature.

The computation of the resulting bending moments in the members is a rather tedious process, as it involves the determination of the angular displacement of each joint. For bridge trusses of ordinary proportions, the deflection is small, and the resulting bending stresses in the members may be safely neglected, but for the shallow trusses with deep gusset plates, they should be considered.

This condition of secondary stress is sometimes further accentuated by faulty joints, such as shown in Fig. 1. The axes of the members are noncurrent, and a bending moment is, therefore, induced at the joint. All members are bent in op-

* Chief Engineer, Pittsburgh Steel Construction Co.

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posite directions at their ends, and by approximately the same amounts. This places them in double curvature and makes a point of contra flexure, or zero moment, at their centers. All members, therefore, resist the bending moment due to eccentricity in proportion to their relative rigidities. The angular displacement of the joint is the same for all members meeting at the joint, and is resisted by all, acting as beams fixed at one end, the joint, and free at the other end, the middle point, where the moment is zero. The angular displacement at the joint then is the deflection of the middle point of any member, divided by the half length of that member, or: $a = \dfrac{M_1\, l}{3\, E\, I}$

where M_1 is the bending moment, resisted by one member, l its half length, E its modulus of elasticity, and I its moment of inertia.

From the above, we have $M_1 = \dfrac{3\, E\, I\, a}{l}$

Since E and a are the same for all members, it is seen that the total bending moment is divided among the several members in proportion to their respective values $\dfrac{I}{l}$

In order to make this result more tangible, and to illustrate the effect of this construction, let us assume an actual case and derive the numerical values of these secondary stresses.

Fig. 1 shows a joint in the top chord of a Warren truss. The make-up and properties of the several members are marked in the figure. Taking A, as a center of moments, we have for the total bending moment, due to eccentricity, 35 600×7.5= 267 000 in. pounds. Apportioning this betwwen the four members meeting at the joint according to their values of $\dfrac{I}{l}$ it is found that each chord section resists a bending moment of 97 000 in. pounds, and each web member resists a bending moment of 36 500 in. pounds. The extreme fibre stress f,

which these bending moments induce, in the members, is given below:

$$\text{For Chords } f = \frac{M\,y}{I} = \frac{97\ 000}{26.94} = 14\ 400 \text{ lb. per sq. in.}$$

$$\text{For Web Members } f^3 = \frac{M\,y}{I} = \frac{36\ 500 \times 2.75}{6.76} = 14\ 850 \text{ lb. per sq. in.}$$

Thus it is seen that the secondary stresses due to ecccntricity are one and one-half times as great as the primary stresses, which alone were considered in proportioning the members.

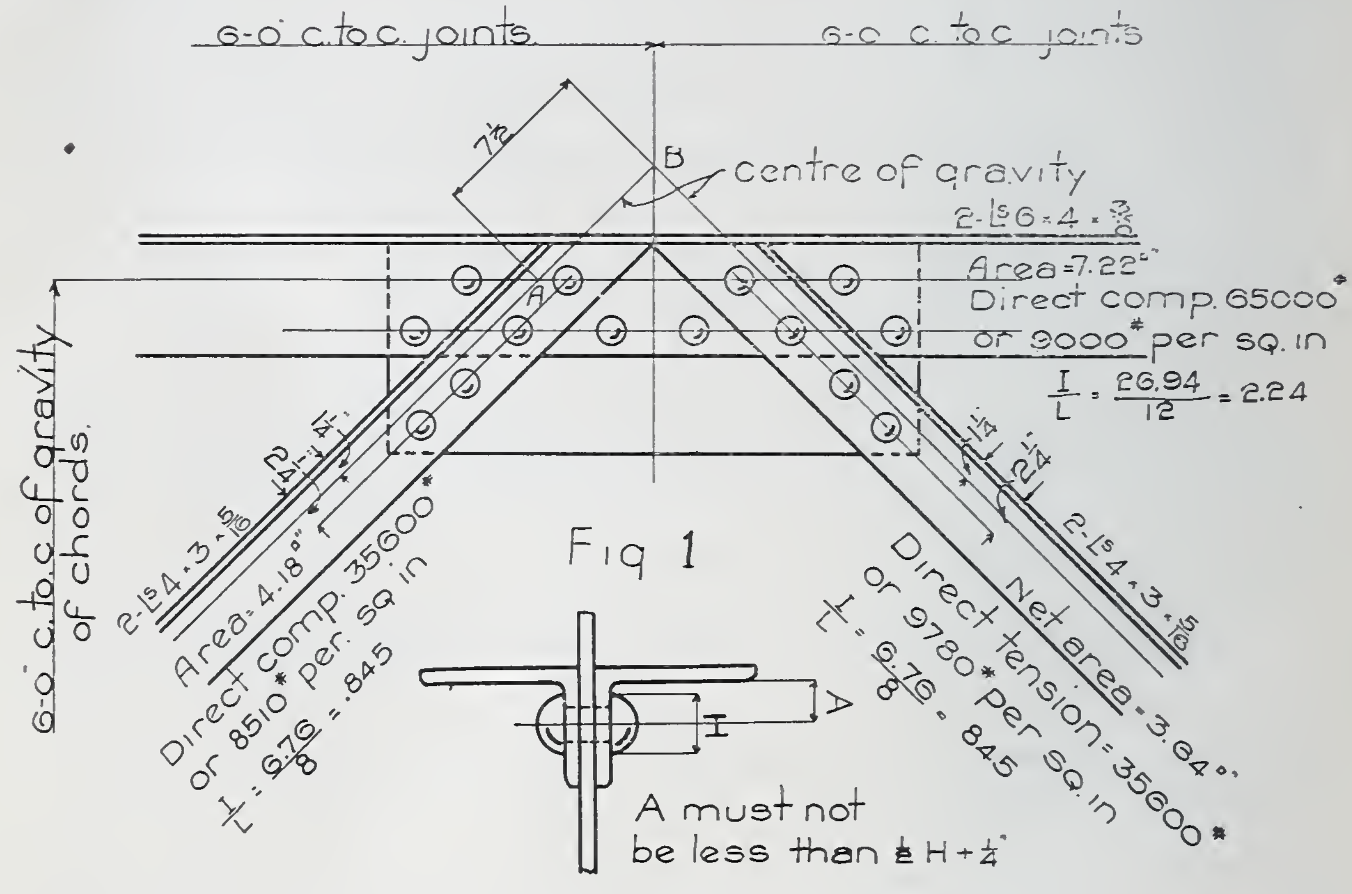

Fig 1

Fig 1a

Another condition which tends still further to increase the secondary stresses in the web members is the eccentricity of the rivet lines to the center of gravity axes of the members. This eccentricity is l, as marked, and the resulting bending moment is 35 600 in. pounds. The general equation for extreme fibre stress for compression member with fixed ends, is

$$f = \frac{M\,y}{I - \dfrac{P\,l^2}{32\,E}} = \frac{35\ 600 \times 2.75}{6.76 - \dfrac{35\ 600 \times 9216}{896\ 000\ 000}} = 15\ 320 \text{ lb. per sq. in.}$$

Particular attention is directed to this result, because this eccentricity of rivet line to center of gravity axis is a fault of very common occurrence in all types of riveted structures. Where angles are used to resist direct stress, and connected through one leg only, the gauge line for the rivets should be set in as close to the back of the angle, or as near to the center of gravity axis as possible. This matter is of fundamental importance, and yet it is habitually disregarded in detailing structural work.

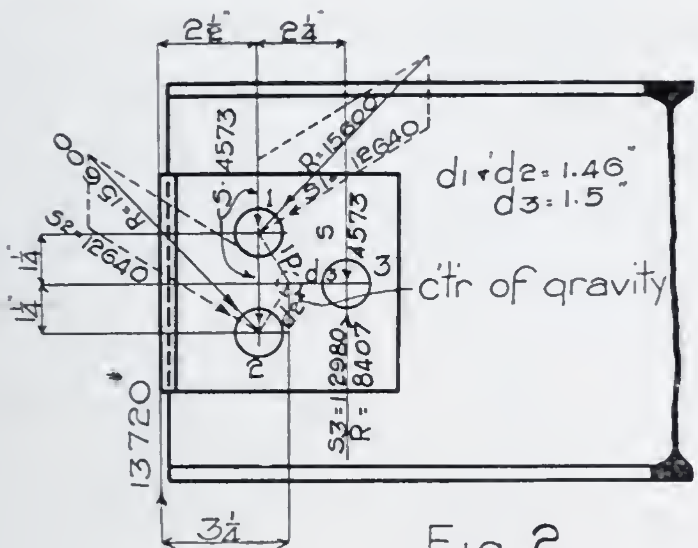

Fig. 2

It is customary to use so-called "standard gauges" for angles, pitching the rivets from the back of the angle a distance somewhat greater than the half width of the leg. The rivet clearance for machine driving is shown in Fig. 1 *a*. In the case of the web members just discussed, the dimension, *A*, would be 15/16 in. Adding to this the thickness of the outstanding leg, we obtain 1 ¼ in. as the permissible gauge of these angles. This coincides exactly with the center of gravity axis of the angles, and if the rivets were so placed, the fibre stress of 15 320 lb. per sq. in. would be entirely eliminated.

Rivets in eccentric connections are sometimes subjected to secondary stresses very much in excess of what they are designed to resist. A good illustration of this is afforded by standard connections for beams. Fig. 2 shows the standard connection for a 10-in. beam 25 lb. section. The Manufacturers' Hand Books give 9½ ft. as the minimum span length for which this connection may safely be used with a beam loaded

to its full capacity. From the table of safe loads, we find that a 10 in. beam, 25-lb. section, 9½ ft. long, will sustain a uniform load of 13.72 tons, giving an end reaction of 13 720 lb., as shown in Fig. 2. This end reaction may be replaced by an equal force parallel thereto, and passing through the center of gravity of the rivet cluster, and a couple with a moment:

$$M = 13\ 720 \text{ lb.} \times 3.25 \text{ in.} = 56\ 290 \text{ in. lb.}$$

Each rivet in the cluster is subjected to a direct stress, $\frac{13\ 720}{3} = 4573$ lb., and a stress due to bending moment.

The stress in any rivet due to bending moment varies directly as its distance from the center of gravity of the cluster, and its resisting moment varies as the square of this distance. Calling, a, the stress in a rivet due to bending at a unit's distance from the center of gravity, we have the equation:

$$M = a\ (d_1^2 + d_2^2 + d_3^2)$$

transposing, $$a = \frac{M}{d_1^2 + d_2^2 + d_3^2} = \frac{56\ 290}{6\ 513} = 8\ 650 \text{ lb.}$$

Now the stress in each rivet due to bending is equal to this figure, multiplied by the distance of the rivet from the center of gravity.

$$S_1 = 8\ 650 \times 1.46 = 12\ 640 \text{ lb.}$$
$$S_2 = 8\ 650 \times 1\ 46 = 12\ 640 \text{ lb.}$$
$$S_3 = 8\ 650 \times 1.5 = 12\ 980 \text{ lb.}$$

These forces are drawn in the figure, and combined with the forces S=4573 lb. The resultant stress on rivets 1 and 2, is 15 600 lb., as shown.

The web thickness of a 10-in., 25-lb. beam is .31 in. The bearing area of a ¾ rivet is, therefore, .31×.75=.2325 sq. in.

15 600 pounds divided by .2325=62 100 lb per sq. in. bearing stress on web of beam. That this is excessive can hardly be denied. Let us hope that in the next issue of the Manufacturers' Hand Books, this table giving minimum span length for which standard connections may safely be used, will be revised.

Fig. 3 shows a joint in a riveted Pratt truss that is of common occurrence. Here the axes of the members are con-

current, but the rivet connection through the chord is eccentric to the intersection of the lines of stress, and a bending moment results. The proper construction of this joint is as shown in Fig. 4.

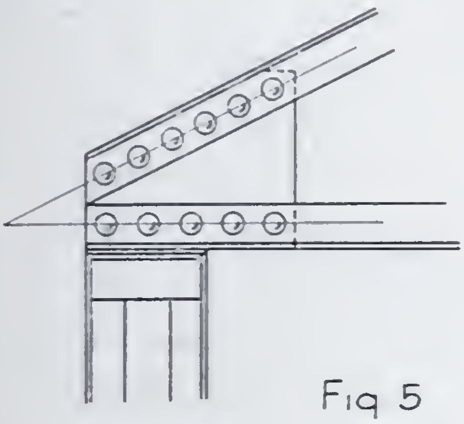
Fig 5

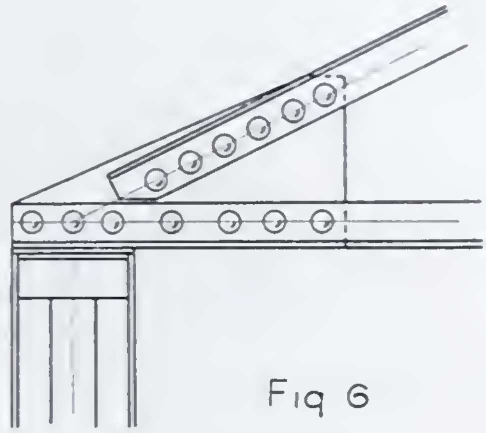
Fig 6

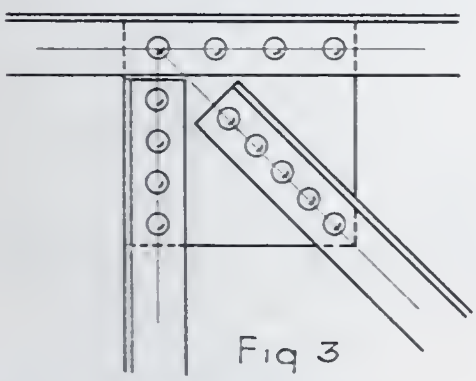
Fig 3

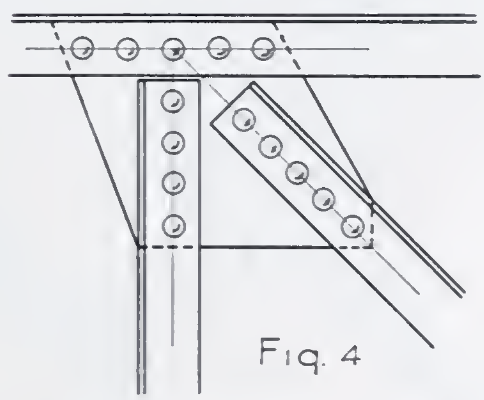
Fig. 4

Fig. 5 shows the heel of a roof truss. This detail has been made familiar by its wide use, and yet the fault is pronounced. The three forces acting at the heel, namely the compression in the rafter, the tension in the bottom chord and the column, or wall, reaction are non-concurrent. A bending moment results which induces large fibre stresses in the members. This detail is susceptible of the same analysis as the eccentric joint of the Warren truss.

Fig. 6 is, likewise, an improper detail unless the heel plate is thick enough to resist the bending moment between the point of intersection of the three forces and its attachment to the members. The plate should also be planed or chipped flush with the backs of the angles of the bottom chord when it is not possible to get sufficient rivets immediately over the column to transmit the total reaction into the plate.

Fig. 7 shows an efficient and proper detail for the heel of a roof truss.

The practice of using ¼-in. and 5/16-in. gusset plates in roof trusses is very common, yet considerations of economy, as well as efficiency, would seem to dictate the use of thick plates. The plates should be of such thickness that the bearing value of a rivet in the plate is about equal to the value of the rivet in double-shear. This would reduce the number of rivets at a joint by nearly one-half, and reduce the size of the plate correspondingly. Whatever slight increase in weight the thicker plates entail is more than compensated by the reduction in rivets. The use of smaller plates and fewer rivets also measurably reduce the secondary bending stresses in the members due to fixity of their ends. This is quite an advantage, and would justify the use of thick plates aside from any other consideration.

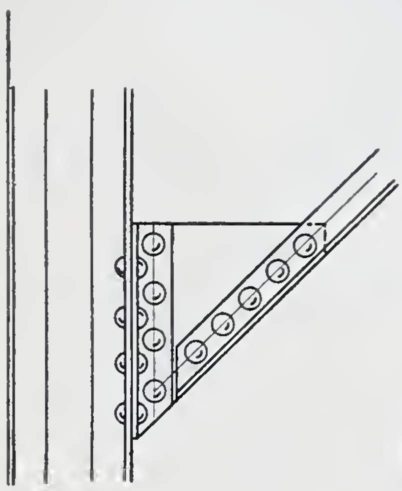

Fig. 8

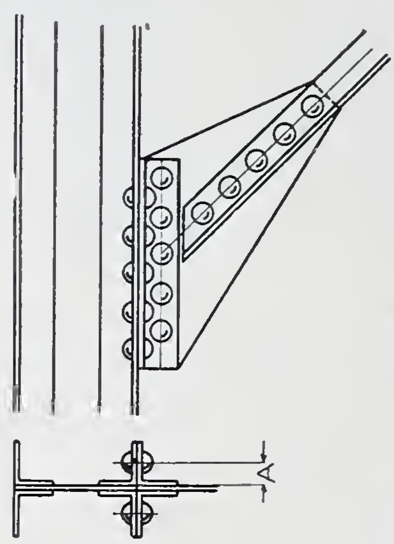

Fig. 9

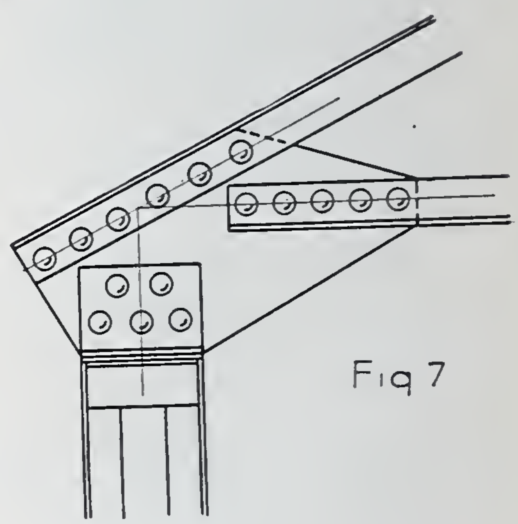

Fig 7

Fig. 8 shows the detail of a knee brace connection to a column, which is not uncommon in mill building construction. This detail is open to the same criticism as the other eccentric connections already discussed. It is especially to be condemned in view of the fact that the knee brace is subject to tension, as well as compression, and when the knee brace is in tension, the entire stress must be resisted by two rivet heads. Fig. 9 shows the proper detail for this connection. The gauge, *A*, for the rivets connecting the knee to the column flange should be as small as possible, and the thickness of the con-

nection angles should be such that their moment of resistance at the rivets is equal to the bending moment. This bending moment is equal to one-half the horizontal component of the stress in the knee brace, multiplied by *A*.

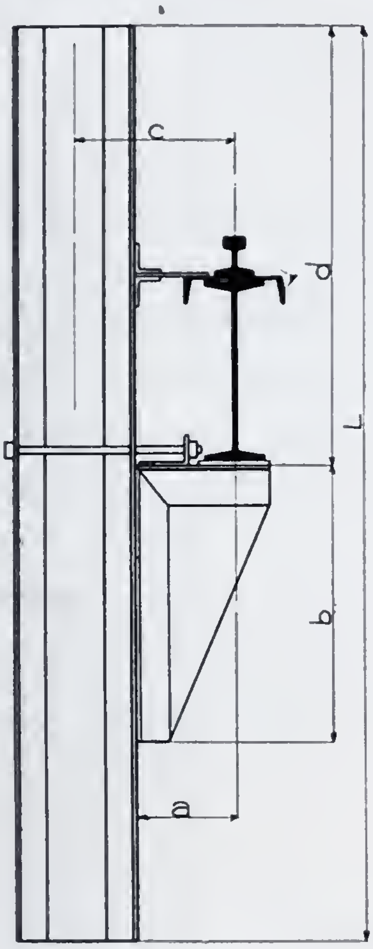

Fig. 10

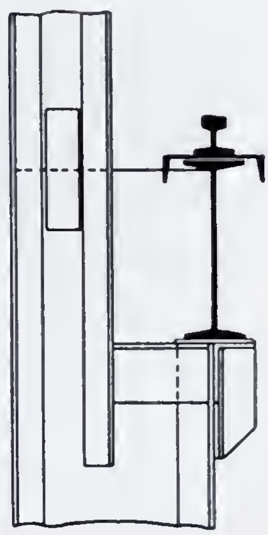

Fig. 11

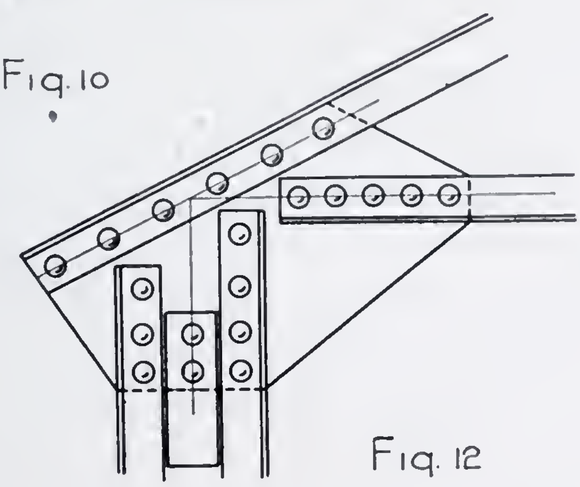

Fig. 12

Fig. 10 shows the detail of a bracket for the support of a crane runway girder. As usually detailed, this style of support has a dangerous weakness, and it has come to be regarded with distrust. When the bracket is correctly detailed, however, and all forces properly provided for, it affords an economical and efficient support for light crane runway girders.

Through bolts should be used at the top of the bracket capable of resisting a stress equal to $\frac{P a}{b}$

The load P being eccentric to the axis of the column, bending moments M and M_1 are induced.

$$M = \frac{P c}{l} \times d \qquad M_1 = \frac{P c}{l} \times \left(L - (b + d)\right)$$

These bending moments, in the case of light cranes, are usually much less than the bending moment at the foot of the knee brace due to wind load, and the bracket attachment requires only a small increase in the moment of resistance of the column. Herein lies the economy of the bracket support over the direct column support, as shown in Fig. 11.

The metal in the wide web plate below the crane seat takes the crane reaction and relieves the bending moments in column due to this reaction, but it does not measurably increase the moment of resistance of the column at the point of maximum bending moment; that is, at the foot of the knee brace.

This leads to a consideration of what is, perhaps, the most common fault in mill buildings with knee braced bents, and that is the inefficiency of the column at the foot of the knee brace. In a very large proportion of the mill buildings, as ordinarily constructed, the column above the crane seat is made from six to ten inches wide, regardless of theoretical requirements, and in most cases the columns are insufficient to resist the bending moments due to the wind load for which the building purports to have been designed. Most specifications for mill buildings that are regarded as standard require that the structure be designed to withstand a wind pressure of 20 to 40 lb. per vertical square foot. Nevertheless it is probable that half the knee braced mill buildings standing today would actually collapse under a wind pressure of 10 or 15 lb. per sq. ft. In view of this fact, an assumed wind pressure in excess of 20 lb. may well be regarded as absurd.

If the columns and knee braces of a mill building about 60 ft. wide with 20-ft. bays and 40 ft. high to the chord were prop-

erly proportioned to resist a wind pressure of 30 lb. per sq. ft., the result would be startling. The columns at the foot of the knee brace would be from 20 to 24 in. deep, and the knee brace, chords and main web members of the truss would be correspondingly massive.

Purchasers of mill buildings seem to derive some satisfaction in specifying high wind pressures, but they usually seem satisfied to accept the design submitted by the lowest bidder. It is hardly necessary to add that this design is made in utter disregard of the specifications. While a designer is, perhaps, justified in disregarding absurd requirements in specifications, there is certainly no justification in many, if not most, of the designs for high mill buildings.

This stricture applies with particular force to such construction as is shown in Fig. 12. This construction is sometimes used, in lieu of a knee brace, in order to economize head room and to avoid obstructing the crane trolley travel. This is a gross and flagrant fault. The knuckle plate should never be used as a substitute for the knee brace in a building high enough for a crane.

Knee braces, at best, are not very efficient, and they should be resorted to only when there is no better method of bracing a building to withstand the horizontal wind pressure.

When a building is of indefinite length, or subject to future extension, knee braces are necessary, as each bent must be self-sustaining, and transmit all of its portion of the wind load to the foundations direct.

In the case of a building of fixed length, however, it is generally more economical to make the bottom chord lateral system a horizontal truss to transmit the wind loads to the gable ends of the building, and thence through diagonal bracing, to the foundations. In this case the eave struts are the chords of the horizontal truss, and they should be made stiff enough to act as compression members, unsupported for the panel length.

Fig. 13 shows a bottom chord lateral system suited to this condition. In all cases, whether knee braces are used or not, the bottom chord lateral bracing should be made continuous

in order to insure good alignment for the columns. This is very important, especially where traveling cranes are used.

Figs. 14 and 14a show two systems of continuous bottom chord bracing, either of which will serve the purpose of aligning the tops of the columns, and, therefore, the crane runways.

Fig. 15 shows discontinuous bottom chord lateral bracing which is not uncommon. Nevertheless it is a glaring fault, and should be avoided even in the cheapest buildings without cranes.

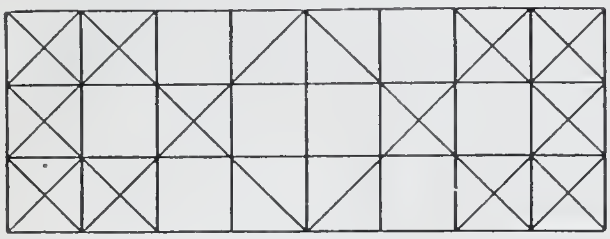

Fig 13

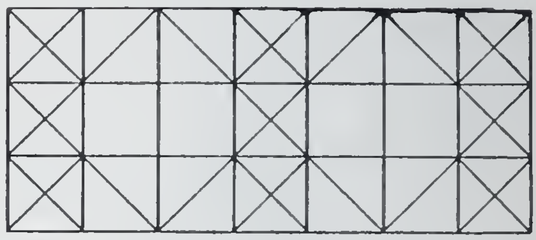

Fig 14

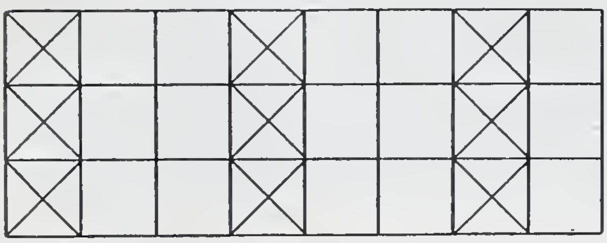

Fig. 15

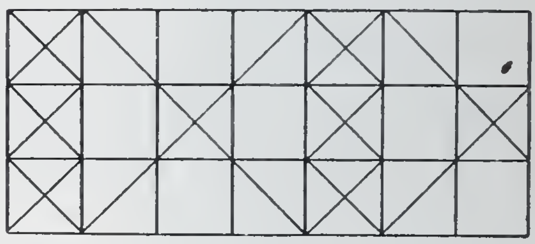

Fig 14a

A few years ago, there came under my observation a building with discontinuous bottom chord bracing where high speed, heavy cranes were in use. Acute trouble developed in the use of the cranes due to bad alignment of the runways. Operation of the cranes was suspended for a few days, and the master mechanic of the plant undertook to correct the trouble by rectifying the alignment of the rails. This was done with a transit, and new holes were drilled in the flanges of the runway girders, where necessary, and the rails clamped in place. On completion of the work, all rails were straight from end to end of building, and no further trouble was anticipated. Operations were resumed, and at the end of a few days, there was a recurrence of the same old trouble. It was discovered that the rails were as badly out of line as ever. The master mechanic was nonplused, and in his uncertainty he was overwhelmed with sug-

gestions from interested employees. Some suggested the reinforcing of the columns below the crane seat, and some suggested the tearing down of the building and its total reconstruction. Sane advice finally prevailed, however, and the trouble was permanently cured by the simple expedient of making the bottom chord bracing continuous throughout. The rails and clips were replaced in their former position, and the building was pulled into line and held there by means of nuts and turnbuckles on the bottom chord lateral rods.

In a building of indefinite length, the function of the bottom chord bracing is simply to prevent the lateral movement of adjacent bents relative to each other, and to reduce the unsupported length of the bottom chords of the trusses. This second function is important because in knee braced buildings the bottom chord is subjected to compression stresses, due to wind action, sometimes in excess of the dead load tension stresses, and it must, therefore, be designed as a strut, as well as a tie.

Of late, there has been a marked tendency toward heavy construction in mill buildings. This is manifested in the many new specifications in which low unit stresses are specified, and in which it is provided that no metal of a less thickness than $\frac{5}{16}$ in. or $\frac{3}{8}$ in. shall be used in the structure. Of course, this provision is designed to procure a stronger and more stable structure, but it fails woefully in its purpose.

It serves only to concentrate metal and weight in parts of the structure where it does absolutely no good. The use of high unit stresses, and the use of $\frac{1}{4}$ in., or even $\frac{3}{16}$ in. metal is not undesirable, if the building is scientifically designed and all details intelligently worked out. The destruction of mill buildings by corrosion is not nearly so rapid as the destructive action of racking forces due to insufficient bracing and faulty details. Unless all the various forces that may act on a building are considered and proper provision made for their resistance, the building will rapidly deteriorate, and soon rack itself to pieces, however low we take our unit stresses, and however thick we make our metal.

In conclusion, it is urged that cognizance be taken of some of the more common faults in existing mill buildings, and steps be taken to prevent their perpetuation.

DISCUSSION.

Mr. W. G. Wilkins: Mr. Pittman's remark about a building supposed to be designed for a wind pressure of 30 lbs., which he thought would collapse under a very much less wind pressure, reminds me of a remark one of my classmates made to me some years after we graduated. He said, as engineer for the Railroad Commission, in a large number of the railroad bridges in a certain State he had calculated the strains in a large number of the railroad bridges in that State, and from the results of his figures he could not understand why many of them had not fallen down long ago, but they were still standing and carrying teams over them every day.

Mr. Willis Whited: It might be well to remind the younger members of the Society that it is not well to place too much reliance on the flexibility of pin-connected joints, especially in old bridges. I have in mind a viaduct whose columns were pin-connected at top and bottom, which, by the settlement of a pier under an adjacent span, was pushed about 6 in. out of place, throwing the columns that much out of plumb, but, instead of the columns hinging at the bottom, as they should have done, they were rusted so firmly into the shoes that, being well anchored to the masonry, one side of the coping was lifted about 1½ in. off the pier. This, of course, involved raising the span about ¾ in.

Speaking of knee braces, I call to mind a building about 75 ft. high, in which the knee braces consisted of two 4 by 3 by $\frac{5}{16}$ in. angles, while the member of the roof truss, which connected to the bottom chord at the top end of the knee brace and had to carry practically all the stress from the knee brace to the other members of the truss, consisted of one 2 by 2 by ¼ in. angle.

As to internal stresses, practically every piece of every

structure contains numerous internal stresses due to punching, riveting and straightening.

Mr. Hermann Laub: Secondary stresses in framed structures are not only due to faulty design, but principally to imperfect workmanship. The abutting joints of compression members are not always accurate, especially on large sections, and must therefore produce eccentric or secondary stresses in adjoining members. Likewise the pin holes cannot be bored accurately, perpendicular to the bridge axis of chord and post sections, which again will cause eccentric or secondary stresses after being connected up to the structure. Such imperfections in the workmanship, which can hardly be avoided, are the weakest spots of our pin-connected bridges and may be of very serious consequences on large spans. This is accentuated by the fact that we do not know to what extent of accuracy the work is or can be done, which makes it difficult to take proper precautions by additional reinforcement of sections.

Secondary stresses are sometimes beneficial to the structure for the sake of stiffness and rigidity. Railroad companies now-a-days build bridges up to 200 ft. spans of riveted trusses, which involve at the joints far more secondary stresses than on pin connected bridges. On ordinarily light roof trusses we introduce knee braces so as to make the structure safe against lateral forces, but we know that such struts are the cause again of secondary stresses in roof trusses and posts to which these knee braces are attached.

These secondary stresses can never be avoided, but must be calculated and taken care of in the most efficient manner, especially if the structures are very large.

Mr. G. H. Danforth: I ran across a case the other day that shows how some people imagine eccentric loading may be avoided. Up in New York State, a job as designed called for a column to be connected to a beam that passed some 15 inches to one side of the column center. The drawing room in detailing put riveted brackets on the sides of the column and rested the beam on the brackets, making a good stiff connection on the column.

The architect on the job condemned the connection at once, and would not have it "on account of the eccentricity of the loading." He made a detail to avoid this eccentricity which consisted of substituting a diaphragm riveted into the web of the plate and angle column for the brackets riveted into the flanges of the column. This, in his opinion, avoided the eccentric loading, but as the point of application of the load remained the same, it would require peculiar reasoning to show how the bending moment on the column was reduced in any way, and certainly the column was not re-enforced. The connection was made as requested, as the matter was not of sufficiently serious nature to call for a protest, but it all forms a rather humorous commentary on present efforts of well intentioned people to avoid conditions that are liable to lead to serious results.

Mr. J. A. McEwen: I noticed a statement in one of the hand books that where a sufficient snow and dead load were assumed the lateral wind pressure could be ignored in trusses up to 100 ft. span. I think, however, that is a very radical statement. The question of taking care of wind stress is one on which there are a great many different opinions.

Mr. P. S. Whitman: We have heard a careful review of the present theory governing the action of secondary stresses. There can be no doubt of the truth of the mathematical deductions; yet how are we to account for the fact that every day one sees structures built in utter disregard of the theory of secondary stress, which still continue to stand up, often carrying external loads much above the limits for which sections have been designed. How are we to account for such contradictory phenomena? The only logical answer is that certain conditions working for safety must exist of which our theory takes no account. In my mind the saving condition is the friction between adjacent parts. The pieces of steel are closely held together by tension on the rivet heads, thus producing a much greater internal resistance than the actual shearing value of the rivets. As this frictional resistance is difficult to estimate mathematically and as its action is always

on the side of safety it seems to be the practice to ignore it completely. However, I think that therein lies the secret why our buildings stand up instead of falling down as they theoretically should.

Mr. Pittman's paper dwelt at considerable length on theory and value of knee braces in a mill building. On this point there seems to exist a wide diversity of opinion. Quite a common mill building detail is to omit the knee braces. The columns in such buildings are frequently called to take heavy bending moments from crane runway girders attached to brackets; which stress must be taken care of by the tensile strength of the column flanges in addition to the wind pressure. In such a design it is apparent at once that the only actual condition which prevents the building from falling over is the stress in the anchor bolts at the base of the column. With a good system of continuous bottom chord bracing the local wind and crane loads at any given column are uniformly distributed to every column base in the structure. No steel in a building can be used to better advantage than that in a good design of continuous bottom chord bracing. The saving grace of such a system does not seem to be generally appreciated. The building without knee braces is simply another example of the fact that our theory considers the stress taking direct path only; while as a matter of fact it may be taken care of entirely, through an indirect path.

Mr. H. S. Prichard: In calculating stresses in trusses and bracing, it is the general practice to assume articulated, frictionless joints, and the intersection at a single point of the axes of all the members meeting at each joint; and it is the further practice to term the stresses so determined "primary."

Not so many years since the determination of the primary stresses was all that was considered necessary, even in cases where it was evident that the assumptions were quite different from the real conditions. In the eighties scarcely anyone but so-called "cranks" paid much attention to arranging riveted connections so that truss members would intersect in common points at the nodes, or to placing pin holes in the centers of

gravity of end posts and top chord sections, composed of channels and cover plates; even after comparative tests at the Watertown Arsenal showed that columns composed of two channels latticed both sides stood more total load than columns composed of similar channels, but with cover plates in place of one set of lattice, when the pins were placed in the center line of the channels instead of placing them in the center of gravity of the cover plates and channels combined.

There has been a marked and commendable tendency of late years to make the actual construction conform more nearly to the theoretical assumptions, where it is practicable to do so without loss of stiffness, and, where it is not practicable to follow the assumptions, to consider the effect of departures therefrom. The paper of the evening is a valuable contribution and should help to establish good practice in these regards.

In the general sense in which the author has used the term secondary stresses, it includes all the stresses which make up the difference between the primary stresses and the actual stresses which the assumed static load would produce; whether due to deformation, to deliberate eccentricity, or to imperfect workmanship or construction.

The method of determining the secondary stresses due to eccentricity in beam connections, which the author has so clearly explained, is similar to the method used and published in an article on standard connections of beams* by the speaker, while he was Engineer of the New Jersey Steel and Iron Company.

The author has expressed the hope that his method of proportioning beam connections will be adopted in place of those now in use. The speaker entertained a similar hope when he published his article on the subject in 1895, and subsequently he wrote to Engineering News† criticising the tables of strength of beam connections, given in manufacturers' hand books, and the methods by which they were computed. To this Mr. Christie, for A. & P. Roberts Co.,‡ and Mr. Thackray,

* Engineering News, 1895, Vol. I, p. 318.
† Engineering News, 1898, Vol. II, p. 43.
‡ Engineering News, 1898. Vol. II, p. 203.

for Cambria Iron Company, replied by making tests, which they published, claiming that they refuted the speaker's criticism. This stimulated the speaker to make a few tests for the New Jersey Steel and Iron Company, which were published in a letter,* which is here reproduced in part, as follows:

"It is well to state the requirements for safe connections. At 16 000 lb. extreme fiber stress, a steel beam has a factor of safety of about two, as regards the beginning of failure, and about four, as regards complete failure; supposing it to fail by bending. The factor of safety required for the connections

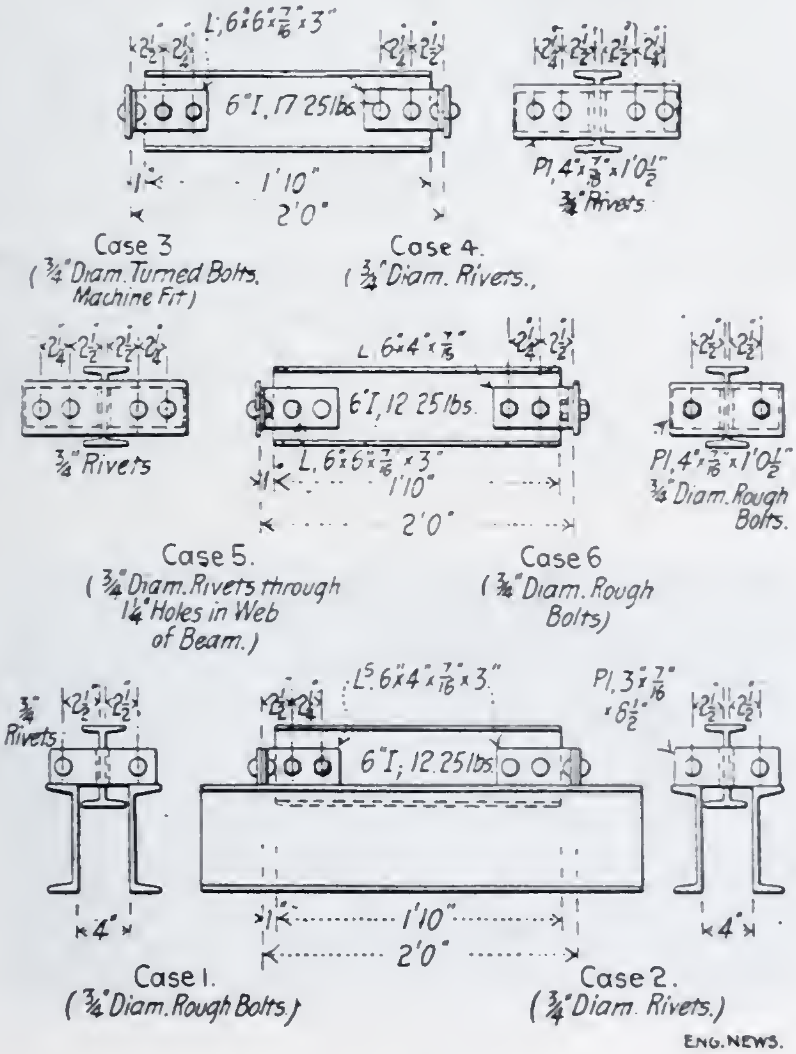

Fig. 16

are illustrated in the accompanying cuts, Fig. 16. The outstanding legs of the connecting angles were riveted to the flat connecting each pair in all cases except No. 6, in which they were bolted. The connection angles were 6 by 4 by 7/16 in. for Cases 1, 2 and 6, and 6 by 6 by 7/16 in. for Cases 3, 4 and 5. The beams were 6 in. 12¼ lb. per ft., with webs 0.23 in. thick

* Engineering News, 1898, Vol. II, p. 203.

for Cases 1, 2, 5 and 6, and were 6 in. 17¼ lb. per ft., with webs 0.46 in. thick for Cases 3 and 4.

In Case 1 the connection angles were bolted to the beam with rough bolts, forced to a bearing before the test, and the nuts were screwed up to a gentle touch only. In Cases 2 and 4 the connection angles were riveted to the beams. In Case 3, the connection angles were bolted to the beam with turned bolts, which fitted the holes, and the nuts were screwed up to a gentle touch only. In Case 5 the connection angles were riveted to the beam, but the holes in the beam were made ½ in. larger than the diameter of the rivets to prevent the rivets from getting any bearing on the beam, the object being to test the frictional resistance from the clamping power of the rivets. In Case 6 the connection angles were bolted to the beam with rough bolts forced to a bearing before the test, and the nuts were screwed up tight so as to give all the frictional resistance practicable. The rivets and bolts were all ¾-in. diameter, the rivets were machine driven, and the holes were punched 13/16 in. diameter, except those for the turned bolts and those in the web of the beam in Case 5.

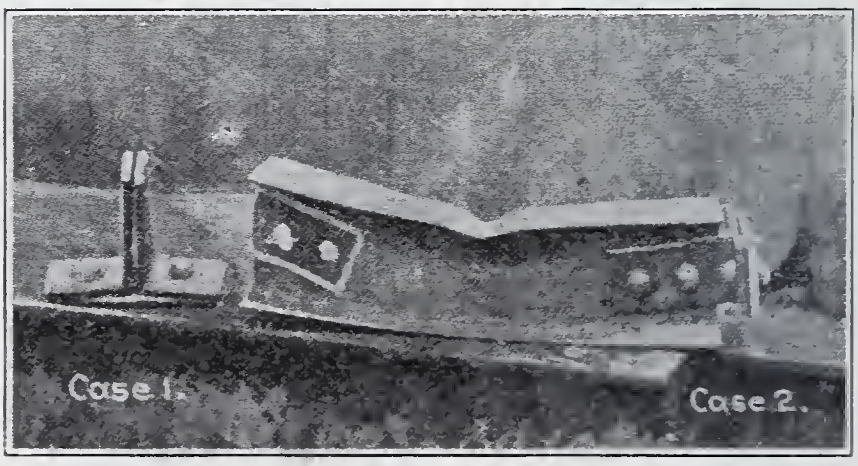

Fig. 17.

It was intended to test the connections only and not the beams, and to insure the beam from failing distributing flats were placed between the top flange and the pressure edge of the testing machine. In Cases 1 and 2 the flats were not added till the beam began to fail.

The results of the tests are given in the table below, to which is added a comparison between the calculated safe loads

for the connections and those indicated by each test separately considered.

RESULTS OF TESTS FOR STRENGTH OF STANDARD BEAM CONNECTIONS.

Case.	Load at the beginning of failure, lb.	Ultimate Load. lb.	Safe Load — Indicated by Test. lb.	Safe Load — Calculated by — Usual Method. lb.	Safe Load — Calculated by — Writer's Method. lb.
1.[1]	2 000	24 900	1 000	6 900	1 470
2.[2]	13 000	......	6 500	6 900	1 765
3.[3]	9 500	17 790	4 450	13 800	2 940
4.[4]	12 500	40 310	6 250	13 800	3 530
5.[5]	2 000	......	1 000	.....	.....
6.[6]	4 000	24 700	2 000	6 900	1 470

[1]Beam split from hole "a" to edge at 22 800 lb., after ultimate had been reached.

[2]Did not fail under load of 24 900 lb.

[3]At 17 790 lb. bolt "a" sheared off.

[4]At 35 000 lb. cracking noise; cause not discovered. At 40 310 lb. rivet "a" sheared off.

[5]Frictional resistance test, carried to slipping point only.

[6]At 22 000 lb. one clip began to crack; at 24 700 lb. bolt "a" sheared off.

In calculating the safe loads by the usual method the bearing value for both rivets and bolts is taken at 20 000 lb. per sq. in. In calculating by the writer's method, the bearing for bolts was taken at 18 000 lb. per sq. in. and for rivets 21 600 lb. per sq. in., to agree with the article on beam connections in Engineering News of May 16, 1895. In obtaining the safe load indicated by each test a factor of two was used with regard to the beginning of failure, and of four with regard to complete failure.

The point at which the connections began perceptibly to rotate with reference to the web of the beam was taken as the beginning of failure. In Case 5 it was possible to obtain this point easily and accurately because after the point was reached the pressure on the machine remained stationary for a few moments. In the other cases, however, it is probable that the results are a little high, as it is difficult to perceive by simple

observation the very slight movement which accompanies the beginning of the crushing of the bearing surfaces.

In arranging for the tests the beams were first supported at the ends by resting the flats connecting the outstanding legs of the connection angles on a pair of channels. After the connection at one end of a beam had failed, a support was placed under the beam at that end.

The load was applied midway between supports in each case, and one-half the pressure indicated by the machine was taken as the load on a connection. In each case the connection angles rotated about an axis perpendicular to the web of the beam, as shown in the photograph, Fig. 17, bringing pressures in opposite directions on the two bolts or rivets connecting the clips to the beam. That the pressure on the bolt or rivet nearest to the edge of the beam was much greater than on the other one was shown by the amount the holes enlarged and by the shearing of the bolts and rivets. The connection angles at each end of each beam also rotated in a plane perpendicular to the web of the beam, and in opposite directions, as shown in the photograph, so that their tops approached each other, producing a toggle joint action, and firmly clamped the beam. The effect of this was to weaken the connection of the outstanding legs to the flat and strengthen the connection to the web of the beam. The clamping pressure developed was in some cases so great that the webs of the beams were crushed a full 1/32 in., and a bearing thus secured at the upper edges of the clips. The strength added to the connection to the web of the beam by this toggle-joint action appears to have been the chief element in causing the high ultimate strength which most of the connections developed. It is probable that it also added considerable strength to some of the connections before failure began. This is indicated by the fact that in Case 2, in which the chance for toggle-joint action was greater and the bearing surface of the rivets less than in Case 4, the point at which failure began was higher than in Case 4. The writer's theory also neglected the partial fixedness of the ends and the frictional resistance from the clamping effect of the rivets and bolts. If the ends were partially fixed it would have some in-

direct as well as direct effect on the strength of the connections by modifying the toggle-joint action, but the writer's experiments have not covered this point. The frictional resistance from the clamping power of the rivets and bolts amounted to 2000 lb. in Case 5. In Case 4, by comparison with Case 3, in which the nuts simply touched, it was probably about 3000 lb., and in Case 6, by comparison with Case 1, about 2000 lb.

That the loads at which failure commenced in Cases 1 and 6, were small as compared with the other cases, is probably due to the fact that the bolts did not fill the holes and consequently had very little bearing at the start (theoretically only a line of bearing.) As the bolts would get their full bearing before failure had progressed very far, the safe load indicated by the tests can hardly be regarded as a fair criterion. That Case 4, in which rivets were used to connect the clips to the beam, developed so much greater ultimate strength than Case 3, in which turned bolts were used, was due partly to the fact that the rivets were initially tight, while the bolts were not, partly to the fact that the rivets were steel, while the bolts were iron, and partly to the fact that the great strength of the rivets made them last longer and thus enabled a greater toggle action to be developed.

The most seemingly astonishing fact was that in Case 1, the ultimate strength was much greater than in Case 3, notwithstanding the fact that in Case 1 rough bolts were used, against turned bolts in Case 3, fewer rivets connected the outstanding legs of the clips to the flats, and the bearing surface of the bolts was 50 per cent less. This fact is probably explained by the greater toggle-joint action permitted by the construction in Case 1.

Mr. Christie's, Mr. Thackray's and the writer's experiments, considered together, show conclusively that the strength of a connection cannot always be obtained by simply multiplying the nominal strength of one rivet (or bolt) by the number of rivets in the connection, and that the strength of a connection depends not only on the bearing and shearing strength of the rivets (or bolts), but also on a number of other

elements. Whether or not it is good practice to rely at all on these elements of strength is an open question."

The speaker is decidedly of the opinion that it is best not to rely on them, especially in view of the possibility of loose rivets. The number of rivets in a beam connection is small at best, sometimes as low as two, and one loose rivet may cause a large proportional loss in efficiency. It is to be hoped that the author will have more success than the speaker had in persuading manufacturers to reduce the amounts indicated in their handbooks as the safe loads for beam connections.

A method of analysis similar to that which the author uses so well in dealing with eccentric beam connections, indicates that even when all the axes of the various members joined by a common connection plate, intersect in a common point, there will be some modification of the stresses if a line of rivets by which a member is connected is placed eccentrically; but the greatest bending moment at any point, instead of being the product of the eccentricity of the line of rivets and the combined longitudinal component of all of the rivets, is the product of the eccentricity and the longitudinal component of, usually, one rivet. A general proof of this proposition is complicated, but it can be easily demonstrated, and the general principles can be readily illustrated by the specific case shown in Fig. 18. Three members, each composed of two 3 in. by 1/6 in. bars, are connected to a common plate, their center lines intersecting in a common point *C*, and each making angles of 120 degrees with each of the others. Two of these members are connected to the plate by rivets located on their center lines, which are likewise their axes. The third, a vertical member *C F*, is connected by a line of three rivets with one inch eccentricity to the right of the axis and spaced 4½ in. on centers. Conceive three forces of 18 000 lb. each, in the direction of the members, to be applied to them at points in their axes at their free ends. These forces, according to the conditions of the problem, will form a balanced system. The member *C F*, separately considered, is held in equilibrium by the downward vertical force of 18 000 lb. at *F*, and forces applied at the rivet points *A*, *B* and *D*. According to the

theory outlined by the author in dealing with beam connections, each of the forces at *A*, *B* and *D* will have an upward vertical component of 18 000 lb. ÷ 3 = 6000 lb.; the forces at *A* and *D* will have horizontal components (18 000 lb. × 1 in.) ÷ 9 in. = 2000 lb. (acting to the left at *A* and to the right at *D*), while at *B*, which is the center of gravity of the group of rivets, there will be no horizontal component.

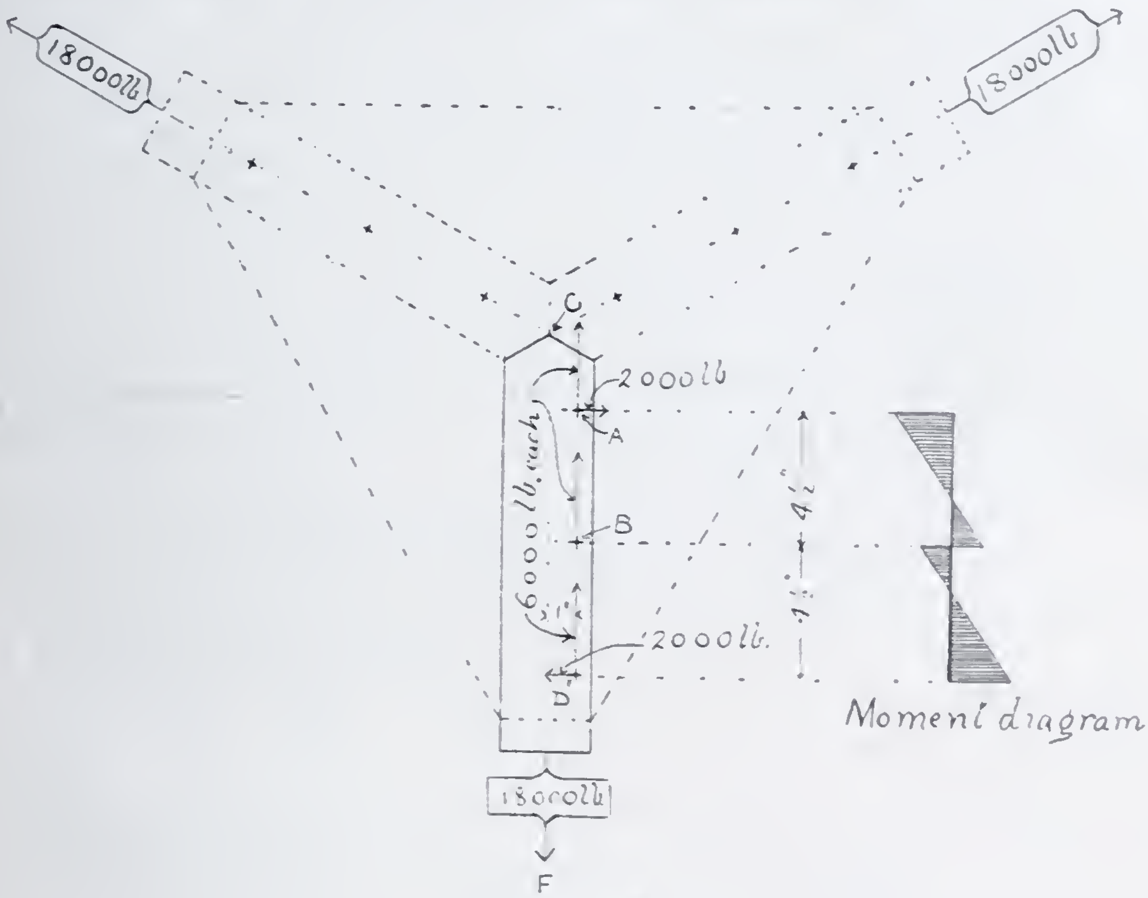

Fig. 18.

As the force at *F* is applied at the axis in the direction of the axis, and as there is no other force applied between *F* and *D*, there will be no bending moment from *F* to *D* but simply a direct tension of 18 000 lb. or 18 000 ÷ (area = 1) = 18 000 lb. per sq. in. of gross section. From *D* to *B*, the direct tension will be 18 000 lb. — 6000 lb. = 12 000 lb., and there will be a bending moment of 6000 in. lb. at *D*:

[(6000 lb. × 1 in.) — (2000 lb. × 0 in.)]

Which gradually decreases to zero and then increases in the opposite direction to 3000 in. lb, at *B*:

[(6000 lb. × 1 in.) — (2000 lb. × 4½ in.)]

At *B*, by reason of the one inch eccentric application of an

additional upward force of 6000 lb., the moment takes a sudden shift to 3000 in. lb. in the former direction, and then gradually changes toward A to 6000 in. lb., in the reversed direction, but shifts to zero at A, as indicated in the diagram in Fig. 18.

The intent of this analysis is not to contend for the absolute accuracy of the method used in making it, but to refute the theory that the member with the eccentrically placed rivets will at any point be subject to a bending moment of the entire direct force times the eccentricity. The assumption that the vertical components of the forces from the three rivets will be equal is not strictly accurate, the eccentric position of the holes will affect the position of the axis, the concentration of pressure at the points of application of the rivets will intensify stresses, and practical considerations, such as loose rivets, may affect the actual stress distribution. In general it is good practice to place the rivets as nearly symmetrical with regard to the axis as possible.

In addition to the secondary stresses pointed out by the author, the speaker calls attention to the bending stresses which floor beams produce in the vertical posts to which they connect; the bending of floor beams and the stresses in stringers produced by the endeavor of the floor system to share in the chord stresses; the stresses in the end connections of floor beams and stringers produced by the effort of the connections to fix the ends; the bending in stiff chords from the deflection of the trusses; and the bending in chords and columns from imperfect butt joints.

In the design for the new Pittsburgh & Lake Erie Railroad bridge at Beaver, Pa., expansion joints in the stringers occur at every second or third floor beam, to avoid secondary stresses from the endeavor of the floor system to share in the chord stresses.

In view of the formidable array of frequently unconsidered stresses of largely unknown amount which the margin of safety is expected to take care of, it is well that there are some circumstances which mitigate the penalty when the said margin is over worked and the elastic limit of the material is, in consequence, exceeded. In many cases it is only a small por-

tion of the material which is overstrained and this portion simply yields to the force it cannot resist, and thereby either relieves the structure of the over-stress or diverts it to other and stronger lines of resistance. The overstrained metal usually does not break but simply becomes plastic as regards the excess stress and recovers from this temporary fatigue with increased ability to resist the kind of stresses which originally overstrained it. There are other cases in which secondary stresses cannot be relieved by overstraining and it is therefore highly desirable that engineers should have a thorough understanding of the principles involved to aid them in forming correct judgments.

Mr. E. W. Pittman: The method of deriving the fibre stress in the angles, Fig. 1, due to eccentricity of rivet line to center of gravity axis has been questioned, and attention directed to the fixity of the ends as a condition tending to reduce this fibre stress. The equation used takes this into consideration and is perfectly general and rigidly correct.

The general equation for fibre stress due to bending moment in fixed end members is

$$f = \frac{M y}{I \pm \dfrac{P l^2}{32 E}}$$

In the case of free end members

$$f = \frac{M y}{I \pm \dfrac{P l^2}{10 E}}$$

In both of these equations the plus sign in the denominator is to be used in the case of tension members and the minus sign in the case of compression members. The second member in the denominator takes into account the small increment of bending moment due to the deflection of the member, equal to direct stress multiplied by deflection. Applying these formulae to the web members of the truss shown in Fig. 1, we obtain the following values:

Compression,	free ends,	f = 17 500	lb. per sq. in.
"	fixed "	f = 15 300	" " " "
Tension,	free "	f = 12 300	" " " "
"	fixed "	f = 13 700	" " " "

DISCUSSION OF PAPERS.

Members of the Society and also other readers of the Proceedings are urged to send to the Secretary written discussion of papers after publication, which will be printed in succeeding issues of the Proceedings. We believe that much valuable information may be presented in this way, and it is hoped that this feature of written discussion may be made a prominent one in the Proceedings.

THE MANUFACTURE OF PORTLAND CEMENT

By Wm. M. Kinney.*

The manufacture and use of cements and hydraulic limes dates back many centuries to the days of the early Romans and Egyptians. It is certain that they used mixtures of trass or puzzolano with slaked lime to obtain a cement which had hydraulic properties. Undoubtedly, too, they were aware that some limestones, when burned, gave limes which were hydraulic.

Until about 1750 it was the common belief among lime manufacturers that the hardest limestones gave the most satisfactory limes, and also that these limes were particularly adapted to sea-water work. About this time, however, the question of the chemical composition of cementing materials was beginning to receive the attention of the chemist and engineer, and in the latter part of the eighteenth century John Smeaton advanced the then unheard of theory that limes depended for their hydraulic properties, not on the hardness of the stone from which the lime was made, but upon the clay content.

This discovery of Smeaton's seems to have opened the way for rapid improvement in the lime and cement industry, for shortly after, in 1796, James Parker, of Northfleet, England, took out a patent for the manufacture of cement. In Parker's process the nodules of argillo-calcareous material were burned in ordinary lime kilns almost to a point of vitrifaction and then ground to a powder. Cement thus produced he called Roman cement, but without doubt it was similar to the natural cement of this country. Likewise in France, the eminent French engineer, Lesage, was experimenting along the same lines and finally produced a similar product at Boulogne-sur-Mer.

* Assistant Inspecting Engineer, Universal Portland Cement Company.

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Cements prepared in this manner rapidly gained favor among engineers and builders. They were not only superior to hydraulic limes in the matter of strength, but owing to the fact that they did not slake on the addition of water, were more adaptable to sea and river wall construction. The popularity of this new bonding material resulted in natural cement plants springing up all over the continent, England, and later, in 1818, the United States.

It soon developed, however, that this cement was subject to great variation, depending as it did on the character of the natural deposit. Some brands showed remarkable strength and uniformity, while others were little better than hydraulic limes. It was very evident that this variation was not due to the different methods of manufacture, but rather to the quality of the raw material, and it is not strange that we soon hear of experiments tending toward the production of a cement from prepared mixtures of argillaceous and calcareous materials.

It remained for Joseph Aspdin, a bricklayer of Leeds, to finally evolve such a mixture, and in 1824 he was granted a patent for the manufacture of Portland cement. To produce this cement certain definite quantities of prepared limestone and clay were mixed together in the form of a mud and made into bricks. These bricks were subsequently burned though it was not stated that the process of burning should be carried on to a point of incipient fusion (an essential in Portland cement manufacture.) This cement, though doubtless little better than natural cement, was a long step in the right direction and paved the way for rapid improvement in the manufacture of Portland cement.

The feasibility of this process being firmly established plants for the manufacture of the new cement were built in many parts of England and France, so that in the early fifties we find Portland cement generally adopted for high class work. Either because of the secretiveness of the British cement manufacturers or because of the excellent quality of the natural cement manufactured in this country, few if any experiments were made to produce Portland cement in the United States

until about 1870. Pleased though they were with their own product, the natural cement men about that time began to realize the superiority of Portland cement. They had noticed that engineers preferred the Portland cement for the better classes of work and it is not strange that they were the first to experiment with its production. A photograph of a pioneer in this movement, David O. Saylor, is shown in Fig. 1.

Fig. 1. David O. Saylor, a pioneer in the Portland cement business.

In his natural cement works at Coplay, Pa., Saylor had for some time noticed that, when ground, the more thoroughly burned lumps of natural cement clinker showed strength far superior to the ordinary run of natural cement. This cement, however, would not stand weathering and subsequently dis-

integrated. To make a cement having the high strength, but not the bad features of this material, was Saylor's aim, and he was not long in coming to the same end attained by Aspdin a half century before, so that in 1871 he had a set of three vertical kilns used exclusively for the manufacture of Portland cement.

These kilns, shown in Fig. 2, were of the intermittent upright type. The fuel and bricks of argillo-calcareous mixture were charged together. The fire was then started and the whole mass allowed to burn until the fuel was entirely consumed. After cooling, the clinker obtained was removed at the lower charging door and ground. Without doubt these were the first Portland cement kilns used in the United States, though about the same time Thomas Millen was constructing a plant at South Bend, Indiana. Plants were soon under way at Wampum, Pa., Kalamazoo, Mich., and Rockport, Me., and despite the fact that three of the first six Portland cement plants were operated for only a short time the industry was squarely on its feet.

Though the American market was at this time familiar with the Portland cement from abroad, it did not at first take kindly to the home product. This prejudice, however, was soon overcome, and, though some 50 years behind the English and French in the first production of Portland cement, the American manufacturers have far out-distanced their foreign competitors, not only in quantity of production, but in the quality of the product and the modern method of its manufacture.

Such was the success of the plant at Coplay that 13 intermittent upright kilns were soon in operation, and in the early nineties improved forms of continuous upright kilns were installed.

One of these, a Schoeffer kiln, is shown in Fig. 3; though these kilns were an improvement on the old intermittent type they were soon abandoned for the rotary kiln of larger capacity and of more uniform burning qualities: likewise the ball mill, tube mill and various special mills soon replaced the old mill stones and dry pans; for dry raw materials, the wet and semi-

wet process, soon gave way to the more economical and satisfactory dry process of manufacture, so that today American made Portland cement is far superior to any other in the world.

Fig. 2. Intermittent Upright Kilns. First Portland cement kilns used in the United States. Still standing at plant of Coplay Cement Manufacturing Company, Coplay, Pa.

Having referred to hydraulic limes, natural cement and Portland cement in the last few paragraphs it might be well before going into the subject further, to make clear the difference in these materials. All consist primarily of lime, silica and alumina, though alumina is a non-essential element in hydraulic lime. In natural and Portland cements alumina acts somewhat as a flux and simplifies the burning process besides forming with calcium combinations of more or less value to the cement. Frequently magnesia replaces a portion of the lime in natural cement. To quote E. C. Eckel: "Hydraulic limes

Fig. 3. Schoeffer Kiln.

include all those cementing materials (made by burning siliceous and argillaceous limestones) whose clinker after calcination contains so large a percentage of lime silicate (with or without lime aluminates and ferrites) as to give hydraulic properties to the product, but which at the same time contains nominally so much free lime that the mass of clinker will slake on the addition of water."

Natural cement is the product resulting from burning (at a temperature only sufficient to drive off the carbon dioxide), argillaceous limestone of such composition that when burned the greater percentage of silica, alumina and iron shall have combined with the lime and magnesia, leaving only a small per cent of free lime.

Using the definition of the Standard Specifications, Portland cement is the finely pulverized product obtained by grinding the clinker resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, to which no addition greater than three per cent has been made subsequent to calcination.

As we are dealing with Portland cement in which slag is a constituent it might be well to define puzzolan cement (so-called slag cement.) The definition given in Professional Papers, Number 28, of the Corps of Engineers, U. S. Army, under the heading of "Slag Cement," is as follows: "This term is applied to cement made by intimately mixing by grinding together granulated blast-furnace slag of a certain quality and slacked lime, *without calcination* subsequent to the mixing."

From the definition for Portland cement it can be seen that raw material for cement is not limited to one particular form of rock, but may be made from any materials furnishing the desired elements. It is not strange, therefore, that we find Portland cement manufactured in this country from a number of raw materials, which, with a few exceptions, may be classed under four heads:

1° Argillaceous limestone (cement rock) and pure limestone.

2° Clay or shale and limestone.

3° Clay or shale and marl.

4° Granulated slag and limestone.

Portland cement may also be divided into classes according to the method of manufacture:

a—Wet process.

b—Semi-wet process.

c—Dry process.

In the wet process (principally for plants using marl), the raw materials are ground and fed to rotary kilns in the form of a slurry containing sufficient water to make it of a fluid consistency. In the semi-wet process a similar, but dryer slurry, is formed into bricks and burned in dome kilns, while in the dry process, most generally used, the raw materials are ground, mixed and burnt in the dry state.

It is about the various mechanical devices employed in Portland cement manufacture that I wish particularly to speak, and to make the subject more intelligible have decided to deal exclusively with the methods used in our plants near Chicago and Pittsburg. A photograph of our No. 5 plant at Universal, Penna. (see Fig. 4), shows the general layout of a cement plant. This plant now has a capacity of 4500 barrels a day, which is being increased to 10 000 barrels per day.

A description of our methods will serve to illustrate general practice in modern Portland cement manufacture, for though we are the only company in the United States utilizing blast furnace slag and limestone for the manufacture of Portland cement, yet with practically no change the same plants could manufacture Portland cement from any of the raw material used.

In the manufacture of Portland cement from granulated slag and limestone the slag furnishes the silica, alumina and part of the lime. To obtain the remainder of the calcium required, limestone is added. To avoid the necessity for frequent changes in the proportions of the raw materials and to secure a uniform product only slag having a uniform chemical composition from day to day is used. This also is true of the limestone; but a necessary feature is the use of limestone very low in magnesia, both as a flux in the blast furnaces furnishing slag and as a raw material to be used with the slag in producing cement. Considering these necessary qualifications the most available furnaces are selected and equipped with apparatus for the granulation of slag. This granulation is done by means of a stream of water under 15 to 18 lb. pressure, directed against the molten slag as it flows into the pits. One

Fig. 4. No. 5 Plant of Universal Portland Cement Company, located at Universal, Pennsylvania.
(1) Raw material trestle. (2) Dryer and raw material building. (3) Burner building. (4) Finishing mill. (5) Stock house.

method of performing this operation is shown in Fig. 5. Here in the background will be noticed the slag flowing from the furnaces down the trough to the "slag gun" located at the end of the pit. A spray of water emerging from the dividing wall between the two sections of the pit hits the stream of molten slag as it comes from the gun and granulates it. By another method of granulation (see Fig. 6) used alternately with this one, molten slag flows down the trough in the middle of the

Fig. 5. Granulating Slag.

dividing wall between the two halves of the pit. From this main trough it may be diverted into either half, and is granulated by a stream of water flowing from under the outlet. This granulation greatly simplifies the handling and grinding of the slag.

As shown in Fig. 6, the granulated slag is transferred in a clam-shell bucket to hopper bottomed cars on adjacent tracks. The limestone also being loaded in hopper bottomed cars, the

handling of these materials at the cement plant is a simple matter. As received they are switched in on the raw material trestle illustrated in Fig. 7. This trestle at our No. 4 plant will accommodate ten cars under the shed and the bins below will hold 1450 tons of coal, 1670 tons of slag and 6130 tons of limestone. Not being hopper bottomed these bins have a large supply of raw material in reserve which can be shoveled in case of necessity.

Fig. 6. Loading cars with slag.

Like flux stones, the limestone is the run of the quarry, ranging in size from about 12 inches in the largest dimension down to dust. From the raw material bins it is fed into the gyratory crushers shown in the foreground of Fig. 8. Here the crushers reduce the stone to sizes ranging from 1½ in. down and discharge direct into the bucket elevators, which raise it to the feed spouts of the rotary dryers. These dryers, of which the stack end is shown in the illustration, are from

30 to 50 ft. in length, according to the type, and about 5½ ft. diameter. They are constructed of steel and lined with fire brick or cast iron.

The rotation of the dryer, gradually feeds the stone toward a flame, which enters at the opposite end. Fig. 9 shows the forward end of a dryer fitted with stoker and forced draft. This furnace uses coal which is crushed in an adjacent build-

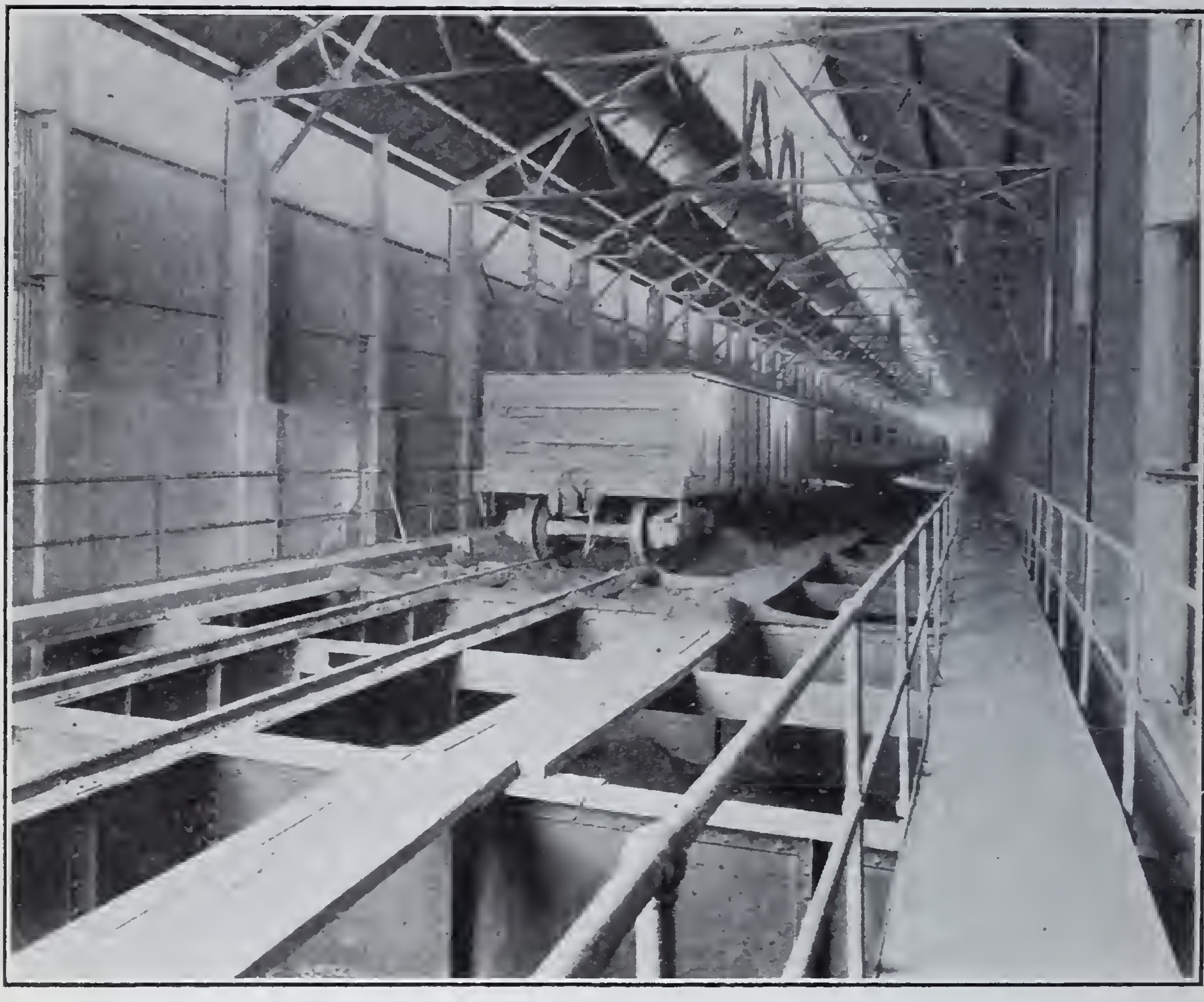

Fig. 7. Raw material trestle, No. 4 Plant, Universal Portland Cement Company, Buffington, Indiana.

ing by William's crushers. The 16 in. air duct in the foreground furnishes the air blast for the furnace, which is maintained at a heat only sufficient to drive off the moisture as it is not the intention to drive off any of the carbon dioxide in this operation.

Another form of dryer uses pulverized coal in a similar type of burner to that utilized for kilns. In this scheme the coal is either pulverized in a separate building, transferred and

blown into the kiln, or is pulverized and blown in by an Aero pulverizer placed in front of the dryer.

Similar dryers are used for the slag and no preliminary crushing being necessary the slag is elevated to the dryer feed spouts direct from the bins. A clam-shell bucket operated by a crane assists in the handling of the slag.

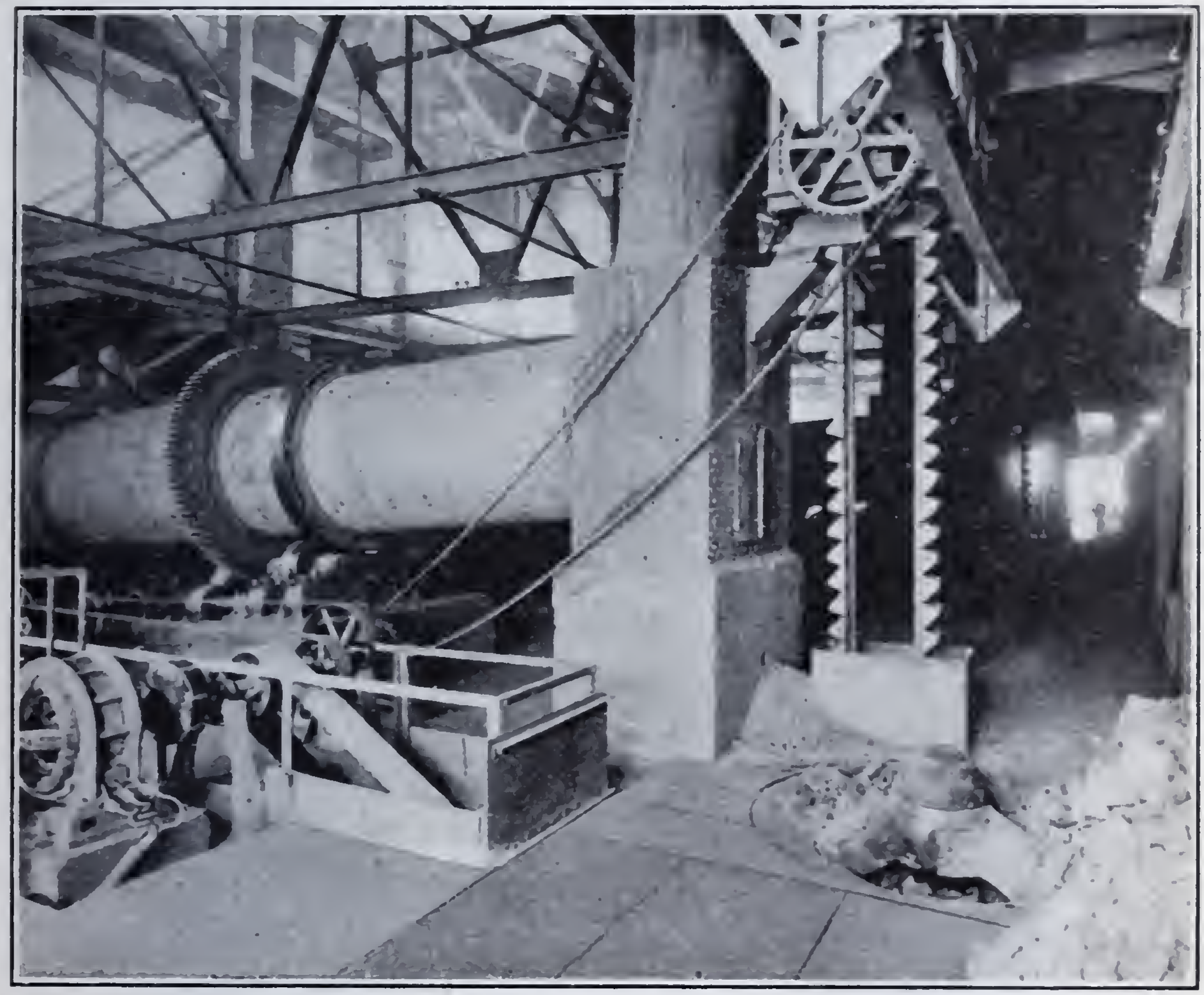

Fig. 8. Limestone dryer, showing crusher and elevator.

Two heavy steel-tired rings riveted to the shell of the dryer (see Fig. 8), about one-quarter the length of the drum from each end rests on cast iron rolls which act as supports for the heavy dryers. The end thrust is taken by horizontal rolls set against the side of these rings and motion is transmitted to the dryers through a large gear secured to the shell just forward of the rear ring. Each stone set, including dryer, crusher and elevator, is driven by a 40 h. p. motor, while the slag sets, consisting of only dryer and elevator, require but 10 h. p.

The "Squirrel Cage" type of induction motor is used for driving the dryers, and in fact, is used quite generally throughout the mills. In manufacturing cement few variable speed motors are required, and considering this the induction motor without brushes is especially adaptable, for a motor with brushes would be at a disadvantage in the dust.

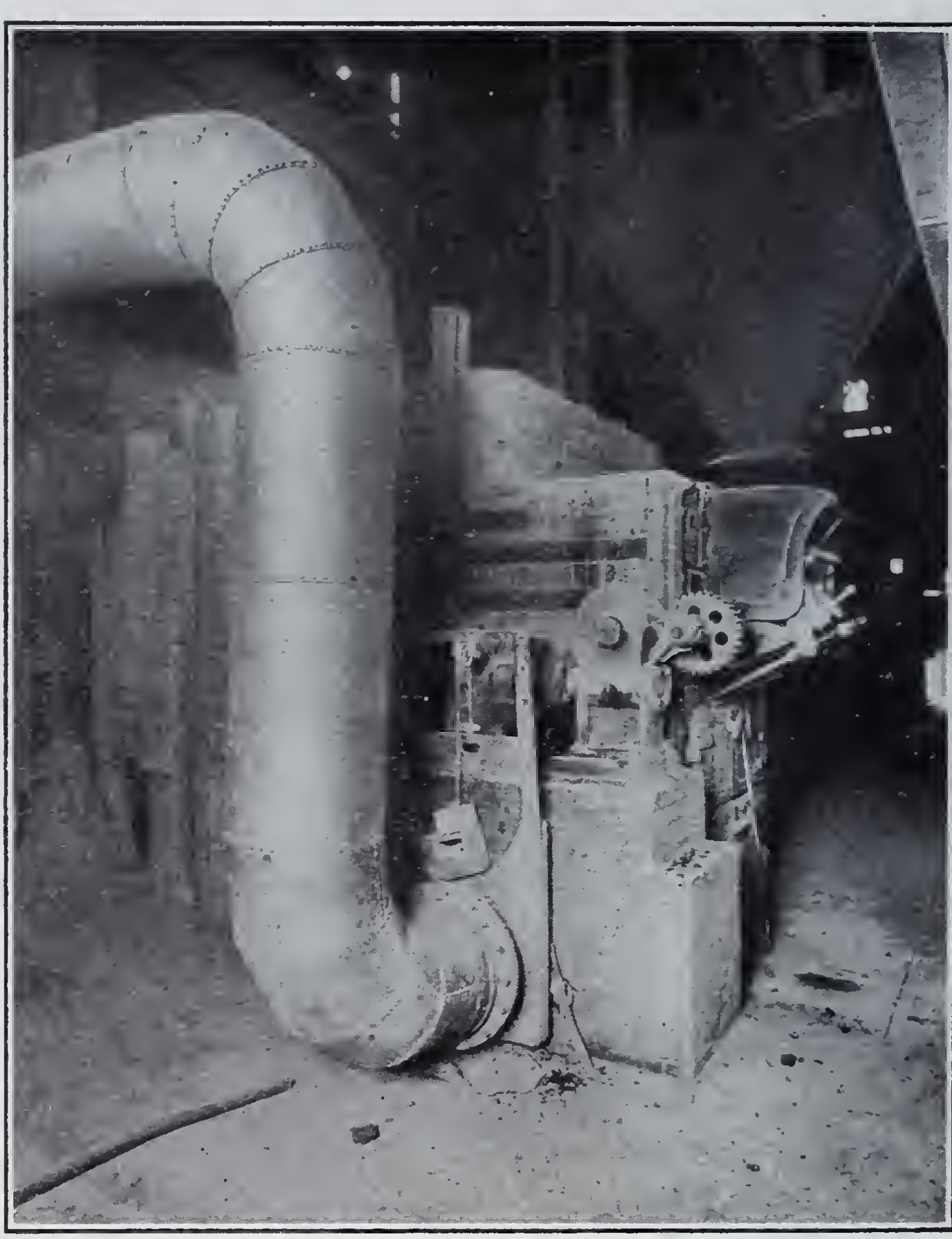

Fig. 9. Stoker for dryers.

Leaving the dryers at the forward end, each of the raw materials is elevated to the storage bins shown in the foreground of Fig. 10. From these hoppers it is fed into the ball mills in which the preliminary grinding is done. This is accomplished by the rolling and impact of forged chrome steel balls (varying in diameter from 3 to 5 in.) on perforated white iron gril-

lage plates. Secured to the same frame and arranged in cylindrical form surrounding the grillage plates are screens through which the fine material must pass before leaving the mill. A light steel shell enclosing this drum acts as a collector for the dust and forms the down spout for the ground material.

Fig. 10. Ball Mills.

These ball mills (Fig. 10) require as an initial load 4200 lb. of steel balls which, to maintain uniform load, must be replenished at the rate of 40 or 50 lb. per week. The arrangement of the grillage plates is such that these balls are being raised and dropped continuously. A 40 h. p. motor driving the ball mill through a set of gears maintains its speed at about 20 r. p. m.

The fine material passing the ball mill screens is conveyed on belt conveyors running under the ball mills to the elevators at the center of the building, where it is raised to the slag and limestone hoppers, above the weighing machines. The material from these hoppers is drawn off by means of screw conveyors which, being driven through an electrical clutch, are automatically stopped when the scale hopper has received the proper weight of material. To secure accurate

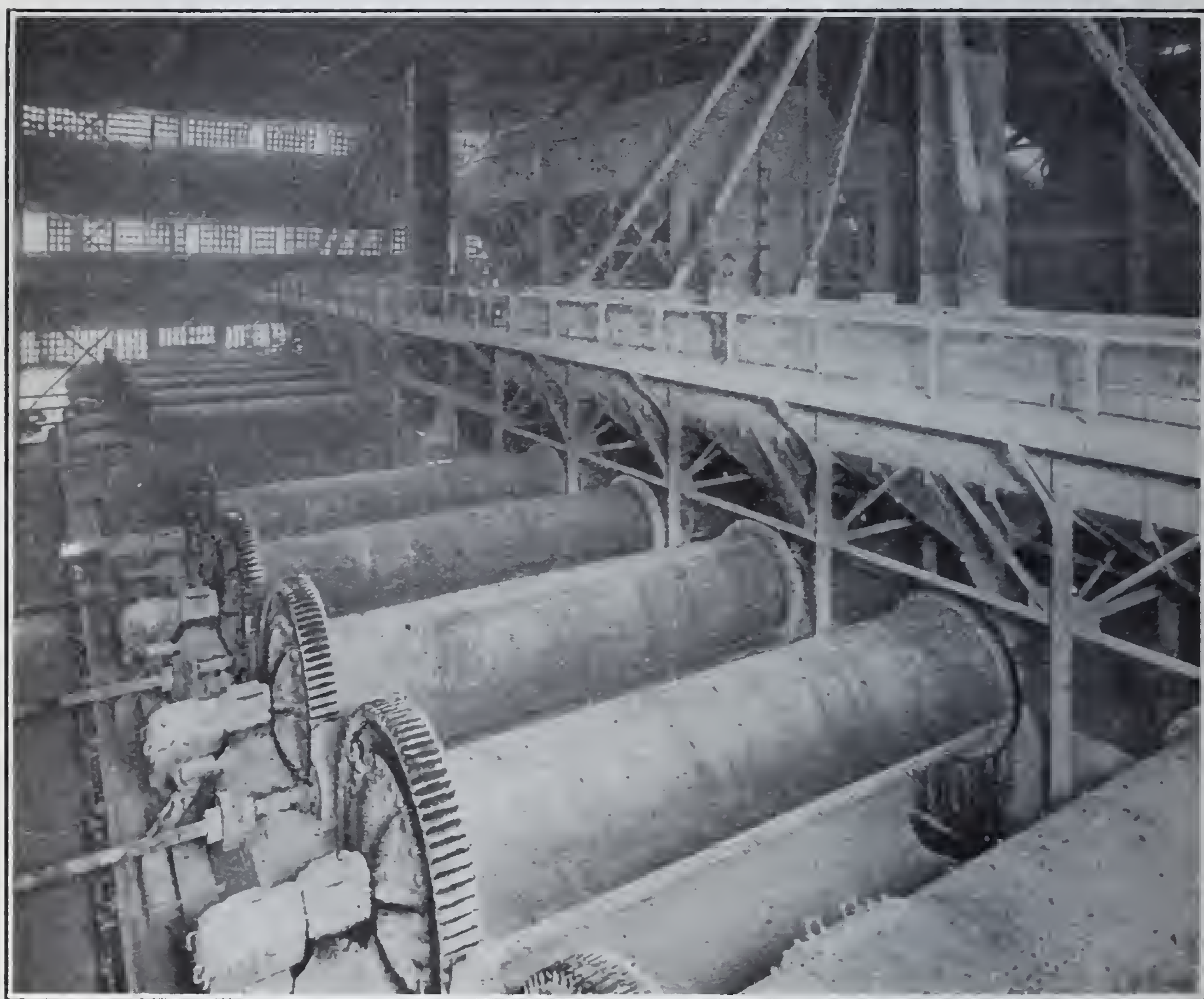

Fig. 11. Tube Mills (raw material).

cut-off the spouts leading from the hoppers to the scales are equipped with shut-off gates which are operated by two small solenoids. A large solenoid operates the release gates which permit the weighed quantities of slag and limestone to empty into the mixing hopper below the platform. The operation of these solenoids and the electrical clutches is governed by the movement of the balance arms enclosed in a glass case on the weighing platform. Each plant is equipped with two such

measuring devices, either one of which can take care of all material passing through the mill.

From the mixing hopper below the scale platform the raw material is conveyed by means of a screw conveyor to the elevator shown in the view of the tube mills (see Fig. 11). The long pipes leading at various angles from the elevators distribute the mixture to the individual tube mill hoppers, from which it is fed into the tube mills. It is in these mills that the final mixing and grinding of the raw material is done.

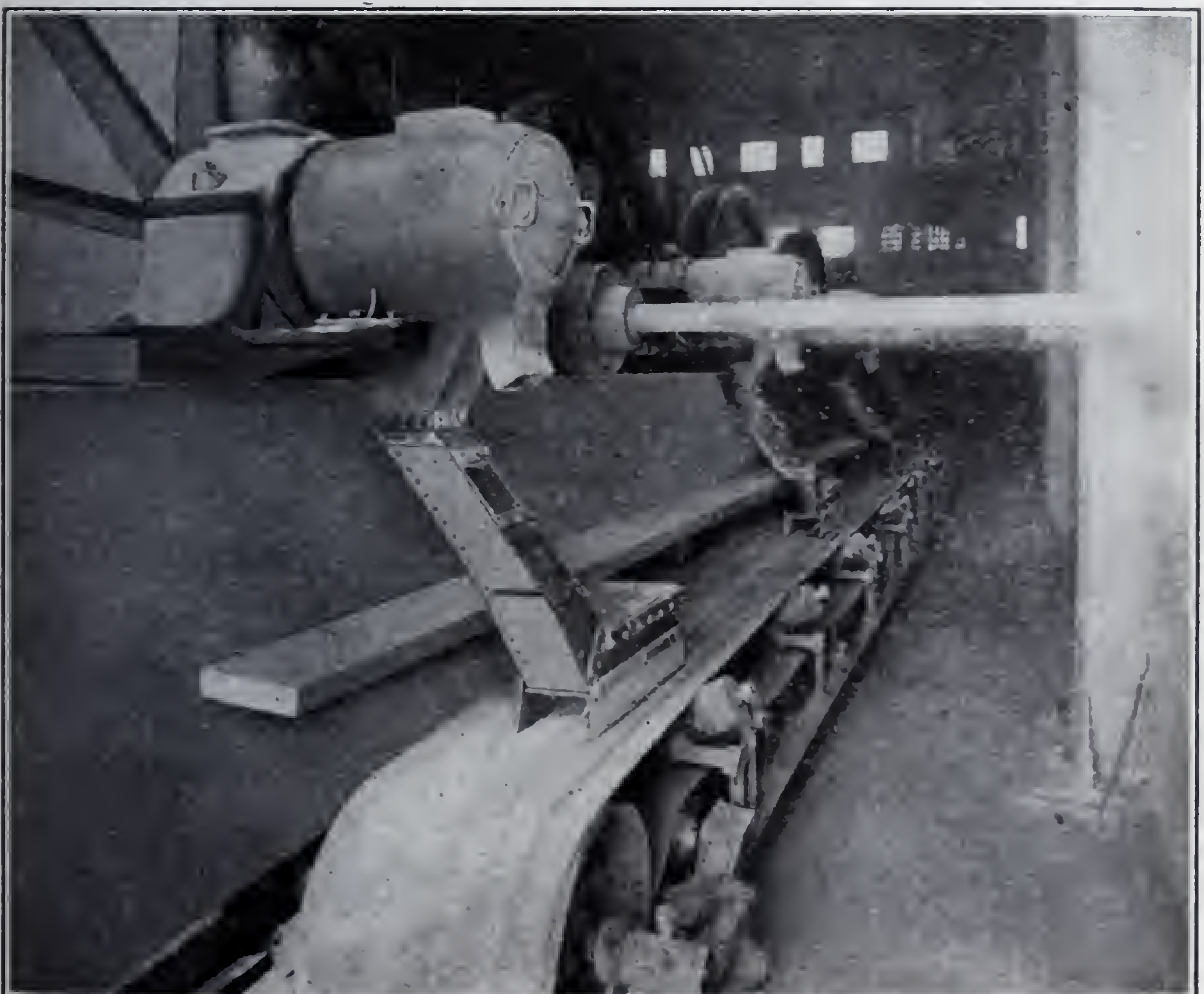

Fig. 12. Tube Mill discharge and conveyor belt.

The tube mills consist of a steel plate drum, with cast iron ends, about 22 ft. long and 5 ft. in diameter. Bolted to the inside of the shell is a white iron lining cast in sections. The tube is partially filled with flint pebbles imported from Denmark or some other northern European country. These pebbles range in size from 1½ to 3½ in., are extremely hard and

will stand a great deal of wear. By their abrasion, one on another, the raw mixture already finely ground is still further pulverized.

As shown in this view, and more clearly in Fig. 12, all the tube mills deposit on the same belt so that again we have a thorough mixing of the raw materials. This is a point which I wish to particularly emphasize as illustrating the many precautions that are taken in a modern mill to obtain uniform quality.

Fig. 13. Rotary Kilns at Plant No. 3, Universal Portland Cement Company, Buffington, Indiana.

The layout of our plants permits placing the motors for driving the tube mills in a building separate from the one housing the mills. Power is transmitted through a flexible coupling to a small pinion which drives the large gear wheel on the discharge end of the mill.

Leaving the belt, the raw material is ready for calcination and is elevated and conveyed to hoppers above the rotary kilns.

These hoppers are shown on the left side above the kilns in Fig. 13. A screw conveyor feed empties the material into a water cooled spout projecting through the brick housing at the stack end of the kilns into the rotating drum.

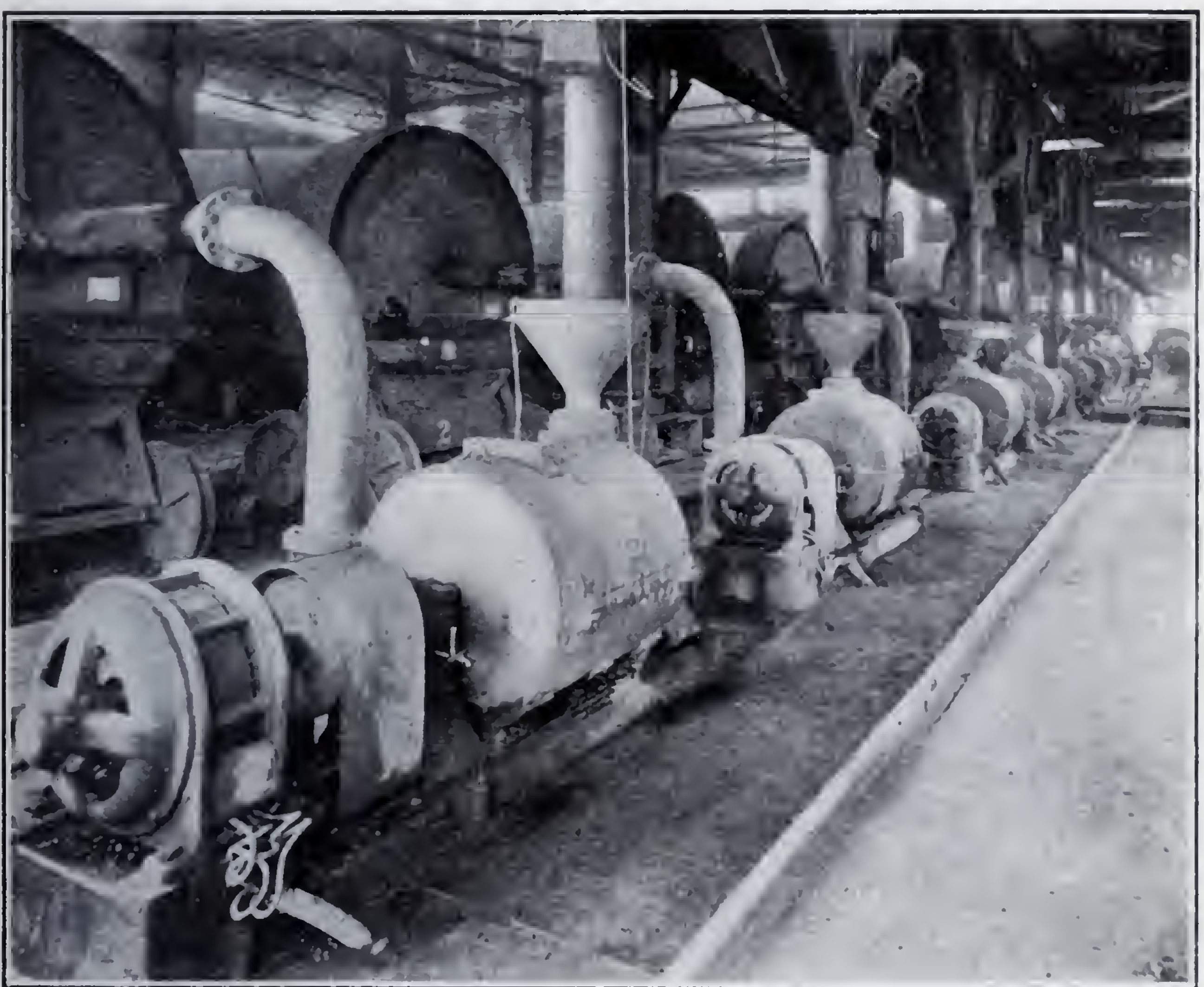

Fig. 14. Aero Pulverizers and forward end of rotary kilns.

The rotary kilns used in burning Portland cement (see Fig. 13), consist essentially of a brick lined steel shell supported at two or more points on heavy rolls. It is enclosed at the rear end by a brick housing through which the waste gases of combustion escape to the stack. At the forward end is a movable steel and fire brick housing such as is shown in Fig. 14. This housing can be rolled back when it is necessary to repair the lining of the kiln.

The steel tires shown in Fig. 13 bear on 24 in. rolls, of which there are four for each tire. Riveted to the steel shell and just forward of the rear tire is the driving gear. On the

concrete foundation, with the bearing rolls, is placed the driving mechanism for the kiln. The kilns operating in our plant range in size from 60 ft. long by 6 ft. in diameter in the first plant constructed to 120 ft. long by 7 ft. 6 in. in diameter in the two started in 1907. A variable speed induction motor drives the larger kilns, which are maintained at a speed of about one r. p. m. The pitch of the kiln with its revolving motion keeps the material flowing steadily toward the flame.

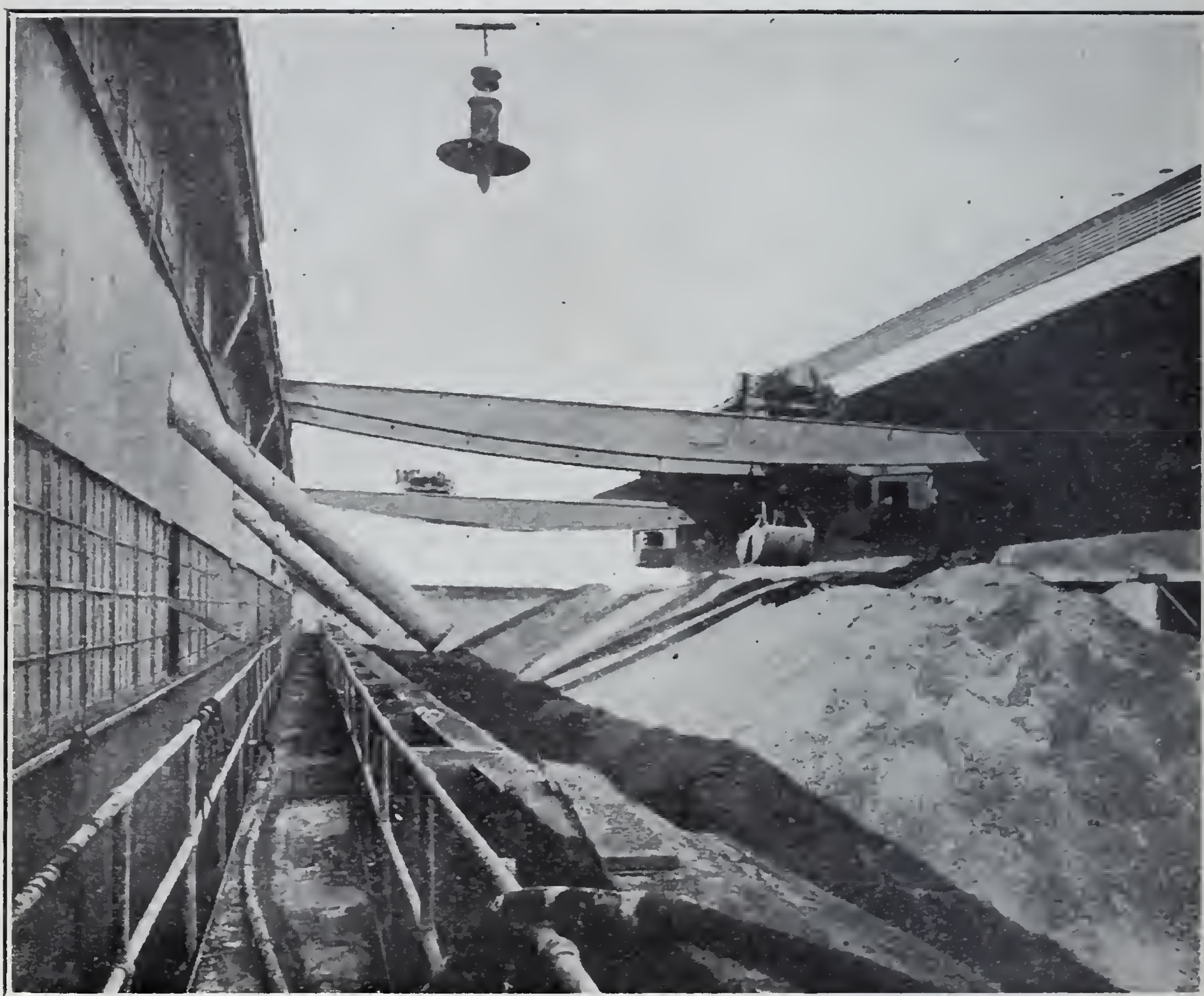

Fig. 15. Clinker storage.

To protect the steel shell of the kilns from the intense heat (close to 3000 deg. fahr.) a fire brick lining is used, varying in thickness from 9 in. at the firing end to 4 in. at the stack end. Powdered coal is used for burning the raw material. It is blown through a light steel pipe entering the center of the front housing of the kiln. We have two methods in use for performing this operation; one in which the coal is

pulverized in a separate building in Fuller-Lehigh pulverizers, while in the other the coal is only crushed before being conveyed to the burner building. The crushed coal is fed from the hoppers above the kilns into Aero pulverizers which powder it and at the same time furnish the blast for the flame. These machines (see Fig. 14) being motor driven, take up

Fig. 16. Clinker Crusher, Maxecon Mill and Newaygo Separators.

but little room in front of the kilns. In the background of this photograph can be seen an auxiliary pulverizer which may be connected with any of the coal hoppers and kiln feeds, thus avoiding the necessity of shutting down a kiln in case repairs to a pulverizer are necessary. When the coal is pulverized in a separate building a screw conveyor feeds the fine coal into the feed pipe and an air blast furnished by a centrifugal blower carries the coal into the kiln.

After passing through the kiln the material is in the form of "clinker" ranging in size from about ½ in. up to 3 in. Leaving the kilns at the forward end, the clinker is discharged into a conveyor or elevator, which in turn discharges it into the clinker storage. Fig. 15 shows the clinker pile at our No. 3 plant. Here the clinker is allowed to remain until it is required for grinding into cement, a two weeks run being usually carried in storage. The cranes, of which there are two for each pit, have a span of 80 ft. and a bucket capacity of 3 cu. yd. They are used to convey the clinker to the clinker hoppers in the finishing mill.

These hoppers are located just beyond the concrete wall shown in the right of Fig. 15, and feed direct into the small crushers shown in Fig. 16. These are simple jaw crushers with removable high carbon steel jaws reducing the clinker to about ¼ in. and under. They discharge into Maxecon mills below, which perform the preliminary grinding. A Maxecon mill consists essentially of three chilled iron rolls about 15 in. diameter set with their axes in a horizontal position. The rolls bear on the inner surface of a revolving ring, contact being maintained by means of heavy yokes and springs.

The material fed to the mills falls on the inner concave surface of the ring. The upper roll is driven and sets the ring in motion at such a speed that sufficient centrifugal force is developed to maintain the material on the inner face of the ring in a layer about an inch deep, so that as the ring revolves the material is carried with it and passes under the rolls successively until it is crushed down and squeezed over the edges of the ring, whereupon it falls to the discharge.

Fig. 17. Tube Mills (finished material).

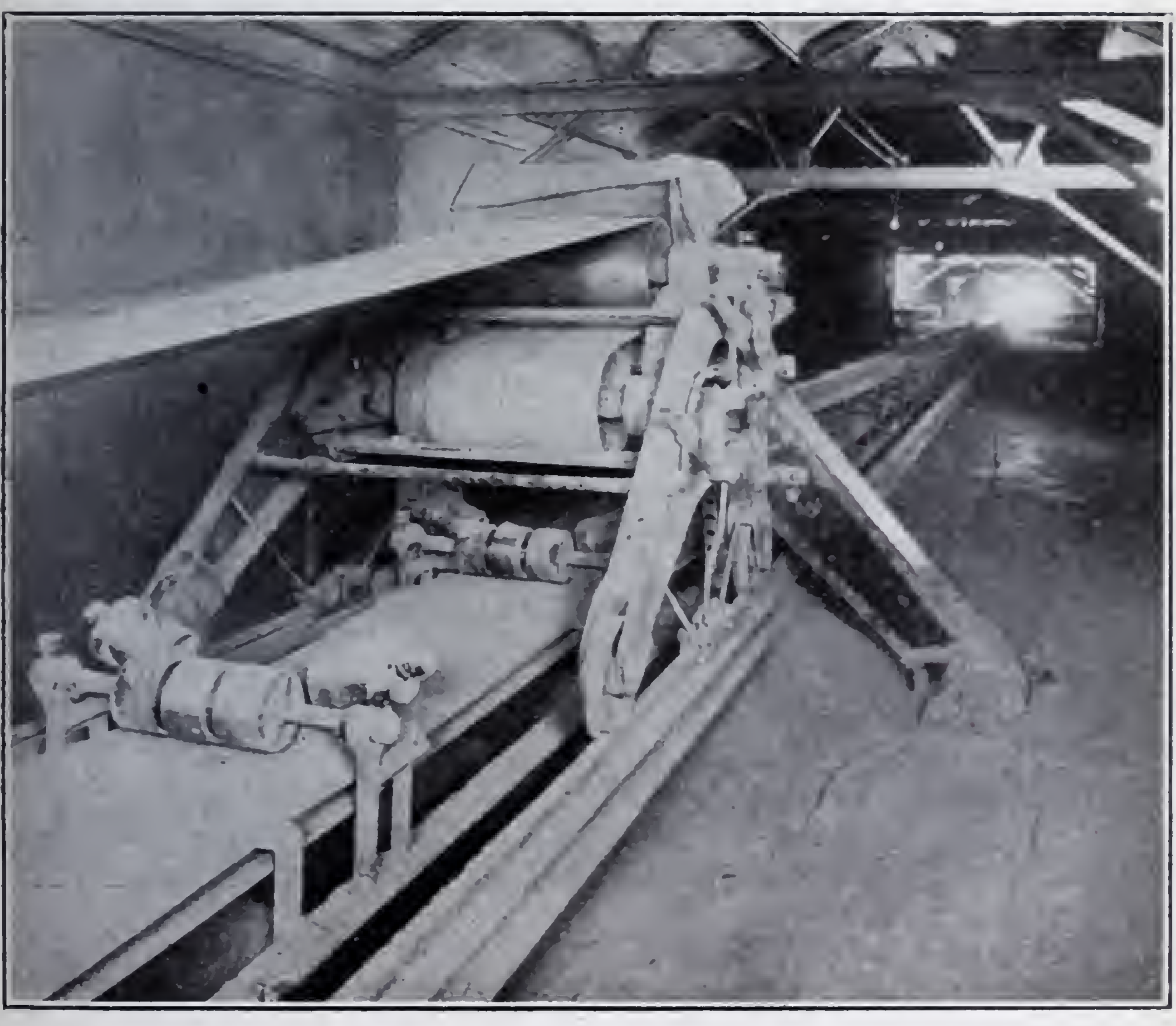

Fig. 18. Cement tripper and belt.

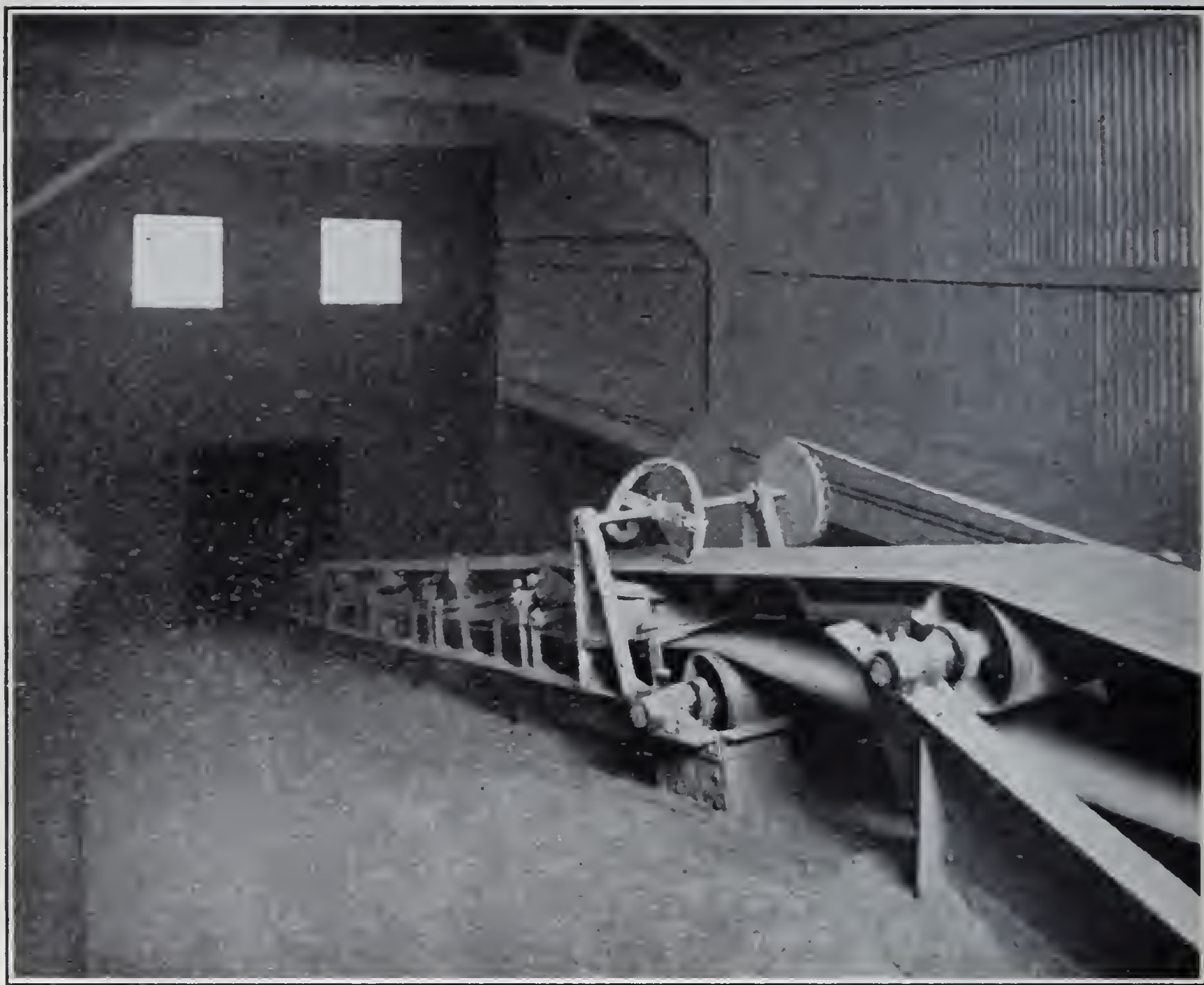

Fig. 19. Sampling device.

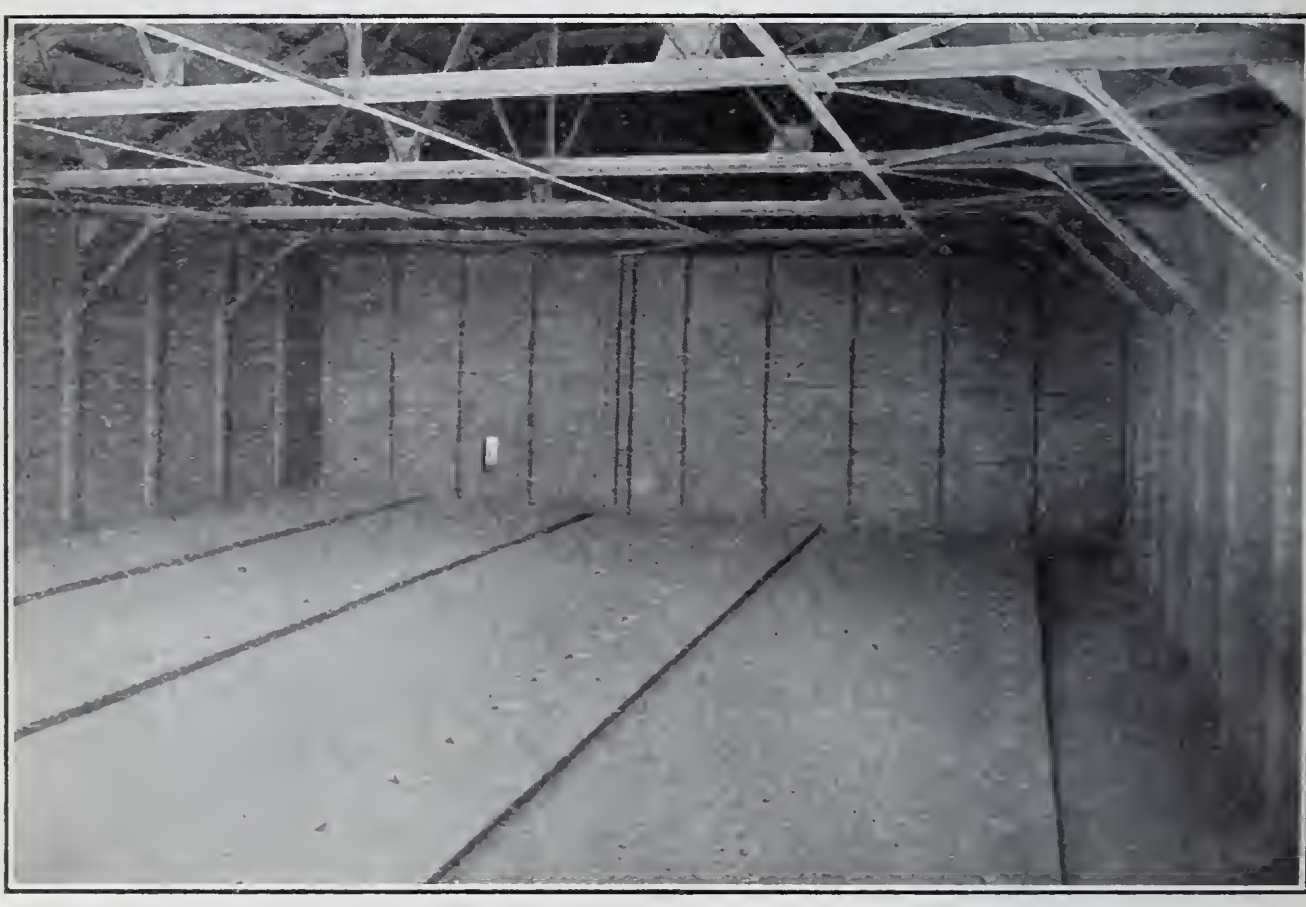

Fig. 20. Cement storage bin (80 000 barrels capacity).

The feed for the Maxecon mills comes from two sources; one (the main feed), direct from the jaw crushers, while the other is a return from the Newaygo separators shown in the background of Fig. 16. In these separators the fine discharge from the Maxecon mills is passed over two screens placed one above the other. These screens reject the coarser particles and return them to the mills for regrinding. A feature of these separators is the method of keeping the screen from clogging. The small shafts above the casing carry small steel hammers, which, as the shafts revolve, knock pins which vibrate the screens. The greater bulk of the raw material passes out through the screw conveyor at the bottom of the separator and is fed to the gypsum adding devices. These machines are so adjusted that to a given weight of clinker there is automatically added a known weight of gypsum. As the amount of sulphuric anhydride (obtained from the gypsum) is limited to 1.75 per cent by the Standard Specifications and 2 per cent by the U. S. Army Specifications, the necessity for such an accurate proportioning device can be appreciated.

Following the addition of the gypsum the material passes to the tube mills (see Fig. 17), where the final grinding of the cement is done. These tube mills are similar to the raw material finishing mills and in them, as in the case of the slag and limestone mixture, a most thorough combination of the cement and gypsum is obtained. A single belt receiving the material from all the mills transfers it to a belt running up an incline to the stock house. This belt, shown with the tripper in Fig. 18, is about one-third of a mile long and extends the full length of the stock house. The tripper shown can be moved the full length of the belt and deposits cement into any of the storage bins.

Both the ground slag and limestone leaving the belts under the ball mills, the raw mixture, just before being elevated to the burner building and the finished cement as it enters the stock house is sampled for chemical and physical analysis by the simple sampling device shown in Fig. 19. This sampler consists of a spiral bent pipe mounted on a shaft which is

driven by a belt from the conveyor roll shaft. The opening at the sampling end of this pipe is reduced so that as the shaft revolves a small quantity of the material on the belt is picked up and carried around in the tube to the discharge end from which it empties into a small box at the side of the belt. At regular periods the samples thus obtained are taken to the laboratories for test and analysis.

Fig. 21. Tunnel under storage bin.

The advantage of a continuous sampler of this type over the common method of taking a snatch sample from the belt can be greatly appreciated, for it gives an average sample of all the material going over the belt rather than of that on one particular section of the belt.

The demand for cement in summer time greatly exceeds the daily capacity of the mill, while during the winter and

early spring it falls below that amount. To permit continuous operation of the mill as well as to insure properly seasoned cement it is therefore necessary to have a large storage capacity. Fig. 4 shows a typical stock house for a modern cement plant. This stock house, including a room at one end for the storage and repair of returned sacks, covers an area of 100 by 700 ft. Three packing rooms extending the full width of this building furnish unexcelled facilities for making prompt ship-

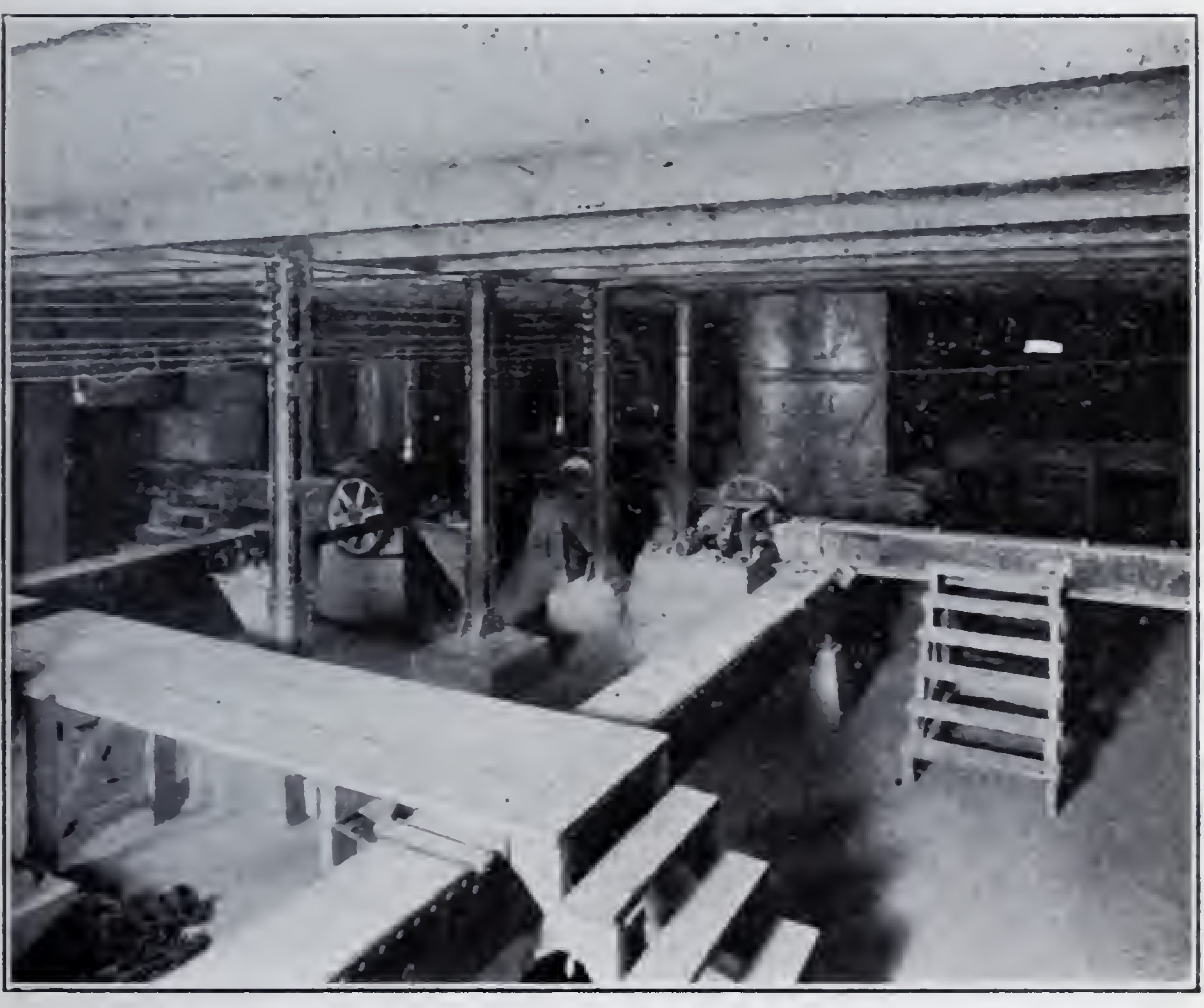

Fig. 22. Conveying machinery in stock house.

ments during the rush season. The bins, of which there are 16, ranging in size from 6000 to 120 000 barrels capacity, will hold approximately 500 000 barrels of cement. One of these bins is shown in Fig. 20. As can be seen in this illustration the stock house is constructed entirely of steel and reinforced concrete so that absolute dryness in the bins is assured.

Slightly above the floor level of the bins will be noticed the tops of the tunnels in which is located the conveying

machinery for removing the cement from the bins. The cement is drawn off through the 11 in. by 18 in. openings shown in the tops of these tunnels and passes through cast iron spouts shown in Fig. 21 to the screw conveyor below. Opening the slides in these spouts permits the cement to enter the conveyor by which it is transferred to the cross-conveyor under the packing room floor. (See Fig. 22.) This cross-conveyor carries the cement to an elevator which raises it to the hoppers above the packers.

Fig. 23. Physical testing laboratory.

Most of the packing in our plants is done by manual labor, as up to the present time no automatic packing machine has entirely eliminated the difficulties met with in handling such material. Several types of automatic packing machines have been tried and other types are to be tried soon, but the tendency of cement to pack in the hoppers and clog up the machinery makes the successful operation of such machine a difficult problem.

During the loading of cars for shipment every tenth barrel or fortieth sack is sampled for check tests. These samples, with the samples secured at the various points in the manufacturing process are taken to the laboratories in the office building where the various chemical and physical tests are made.

Fig. 24. Chemical testing laboratory.

Fig. 23 shows a corner in the physical testing laboratory. This laboratory is located in the basement of the office building. Occupying a similar position at the other end of the building is a similar room set aside for the use of testers connected with outside laboratories. It is in the physical testing laboratory that the tests for fineness, soundness, tensile strength, etc., are made, while above on the main floor of this building the chemical laboratory is located (see Fig. 24), where the various chemical analysis of the raw and finished materials are made. Here is determined the chemical composition of the slag and limestone prior to mixing, of the raw

mixture and of the finished product. There also analysis is made of the coal and gypsum, as no materials are used until they have been accepted by the chemists.

The building in which these laboratories are located also contains the general mill offices. The exterior finish of this building, which is constructed entirely of concrete, is known as a brushed surface. After the removal of the form lumber the exterior wall was treated with a weak acid solution and the cement brushed out, leaving the aggregate exposed.

Fig. 25. Office Building, Plant No. 5, Universal Portland Cement Company, Universal, Pa.

Electric power is used throughout the mills. It is generated by gas engines at the Carrie Furnaces and transmitted at 60 cycles and 22 000 volts over a three-phase line to the transformer station (see Fig. 26), where the voltage is reduced in 50 to 1 transformers to 440 volts, the voltage almost universally used throughout the mill. The motor generator sets shown in the foreground of this view are used to convert the 440 volt alternating current to 110 volts direct for lighting purposes. The motor-driven pumps in the background furnish

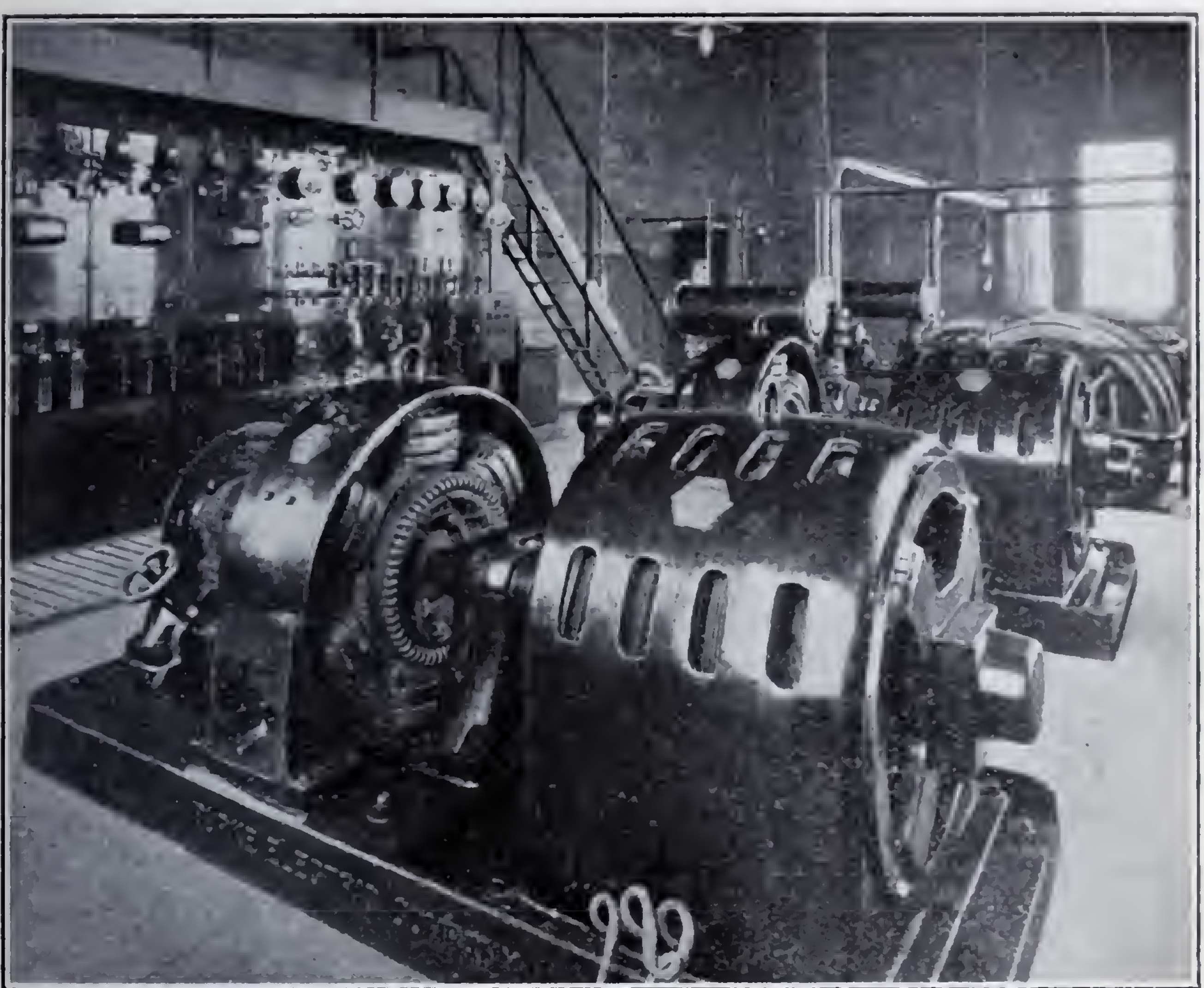

Fig. 26. Transformer and Power Station.

air for cleaning motors, pumping water and general use around the plant.

From the foregoing description of our plants it can be seen that the manufacture of Portland cement is now on such a basis that a high grade product of uniform quality is assured. The remarkable growth of the industry is not equalled by that of any other manufactured article, and particularly is this true of the Portland cement made from slag and limestone, for the output of this company has increased from less than one-half of one per cent of the total output of the United States in 1900 to more than 11 per cent in 1908.

DISCUSSION

Mr. J. K. Lyons: It is of special interest that cement is to a degree supplementing the use of steel. One feature about cement production is, that it requires considerable capital to finance such a business, and another is, the abundance of raw material scattered over the country suitable for its production.

In connection with its manufacture in the state of Kansas, regarding which we are not so particularly interested or so well posted, they have apparently been able to use natural gas successfully in the burning. About this, however, we have little information, and as to the operation of the kilns under such circumstances the public are not informed.

Judging from the price at which they are able to get natural gas, however, it may not matter whether it is an economical application or not. I understand they figure on natural gas at about three cents per thousand cubic feet, at which figure they can probably afford to use plenty of it in burning the product, but with the use of pulverized coal, the fuel cost becomes a very important item.

I suppose for calcination purposes the fuel will run anywhere from 70 up to 150 lb. of coal per barrel of cement produced, depending on conditions and method of operation. I have seen it stated that the coal consumption per barrel of cement, for burning and other purposes, is from 200 to 300 lb. To the ordinary observer, it appears to be a pretty large quantity of fuel for the production of 380 lb. of finised material.

The Author: Regarding the operations in Kansas I might say that because of cheap fuel most of the mills use the wet process. It is easier to grind the raw material in the wet state and inasmuch as the gas for burning is so cheap they can afford to use a good deal in drying out the raw material. The plants in the Kansas district should be given as exceptions to the broad statement I made to the effect that all modern plants used the dry process.

Mr. J. O. Handy: I would like to ask whether the object of cement manufacturers is to make a cement which will show a high tensile strength in a short time or a moderate degree of strength at first and steady increase afterward. Within what limits are you able to hold the calcium oxide in the finished cement with your mechanical methods of weighing, mixing, etc.

The Author: The manufacturers aim to make a cement which will show gradual and uniform increase. The variation from day to day is very slight, and assuming a normal lime content of 63 per cent, I do not think that it will vary more than half a point either way.

Mr. L. P. Blum: What is the real variation of the slag from a chemical standpoint? Is the slag used uniform in composition or does it vary constantly?

The Author: The slag used for Portland cement manufacture shows very little variation in chemical composition. Only uniform grades of ore and limestone are fed to the furnaces, so that the resultant slag shows practically no change from day to day.

Mr. J. A. Ferguson: I would like to know the degree of fineness to which the raw materials are ground before making the clinker in the first place.

The Author: The quality of a cement depends to a great extent on the fineness to which the raw material is ground. The fineness of our raw material runs from 88 to 92 per cent through the 100 mesh sieve, which insures intimate combination of the two raw materials.

Mr. R. S. Feicht: Is the cement dust much of an abrasive, and if so, what effect does it have on gears and bearings throughout the mill, particularly on the motor bearings. The motor bearings are supposed to be dust proof, but it is practically impossible to keep all the dust out of them. What effect has the dust on the operatives? Is the useful life of an operative in the mill limited on account of the dust?

The Author: The dust in a cement mill is a difficult feature of the process of manufacture to eliminate. Various schemes are employed to keep the dust from the bearings and gears, but even under the best circumstances they require careful watching at all times. Wherever possible the motors

and driving machinery are protected from the dust by coverings or partition walls.

The effect of the dust on the operatives does not seem to be harmful, except in those parts of the mill where free breathing is impossible. In such places the men wear a sponge or some such device to keep the dust from their lungs.

MR. J. A. FERGUSON: What is the action of gypsum and what percentage of gypsum is added?

THE AUTHOR: The action of a small percentage of gypsum on the setting time of cement is rather peculiar. Gypsum as well as finely ground cement clinker is quick setting, yet a combination of a small percentage of gypsum with this cement causes the retardation of the setting time of the whole mass. The amount of gypsum which can be added is limited to 3 per cent by the definition for Portland Cement of the standard specifications, but the amount added in most mills seldom exceeds 2 per cent. Most of the sulphuric anhydride in cement comes from the gypsum, and as this is limited by the standard specifications to 1.75 per cent, it is necessary to hold the gypsum content to a minimum.

MR. J. A. FERGUSON: What keeps the fine particles in the clinker pile from setting when it is exposed to the air and weather?

THE AUTHOR: The amount of material in the clinker pile that would pass a ¼ in. mesh screen is very small, and of this material the percentage, which would be active in producing bond, is negligible. Only the impalpable powder in cement is useful in producing adhesion and these minute particles are so widely disseminated that no setting can take place in the clinker pile, which would materially affect the cement.

MR. W. M. JUDD: What coal do you use for your plant?

THE AUTHOR: For burning the cement we use coal from what is known as the Pittsburgh vein. I believe it is obtained from the New York and Cleveland Gas Coal Company.

MR. C. A. NORTON: I would like to ask as to the relative importance of the tension and compressive tests. It is almost always tested by the tension machine, but it is only used in compression, and I would like to know the reason for that?

THE AUTHOR: As far as its value in concrete is concerned the tensile strength test is of use only as a comparative test between different brands of cement and different grades of aggregate. Concrete is seldom used in tension, but the inability of the testing machine manufacturers to furnish a satisfactory compression machine for small specimens has led to the extensive use of the tension machine. It would, of course, be much more reasonable to judge a cement by its compressive rather than its tensile strength, as it is the compressive strength which gives it the greatest value as a building material. Tensile tests, however, by the use of a proper factor give fair indication of the compressive strength to be expected.

MR. R. S. FEICHT: How long does it take for the raw material to go from one end of the mill to the other, from the beginning to the end of the process, assuming that it is continuous.

THE AUTHOR: It has been roughly estimated that it requires 6 hours for a particle of material to pass through the various stages of manufacture. This assumes, of course, that the clinker is not stored for a period of ten days or more as in actual practice.

MR. EDWARD GODFREY: The principal difficulty in making compression tests as compared with tensile tests is not so much the cost of the machine as getting a cushion to give a uniform bearing on the end of the block and getting the block uniform in size and having the ends parallel. It is difficult to get a material that will act as a cushion. Sometimes cement is used, the test piece being placed under some compression during the setting. The test piece could not be allowed to set in the machine without having the machine lie idle for too long a period. Plaster of paris is not the same strength as cement

and the results are not very satisfactory. Cement will not set up to the same hardness as the test pieces. So I think the principal difficulty in getting compression tests is the difficulty of getting a suitable cushion. I have used half-inch pine blocks, but even with these the test piece crushed on a high side first.

The Author: Plaster of paris has been used quite successfully for lining up compression test specimens at the laboratories of the United States Geological Survey, structural materials division, as well as in a number of universities. After a little practice it seems to be a very simple matter to obtain perfectly flat and parallel ends on the test specimens.

Mr. J. A. Ferguson: It seems to me the difficulty of testing cement in tension is about as great as that in compression. There are some very admirable ways of lining up the end bearings, so that variation from this source is less than the variation in actual strength of cement tested in compression. But for tension tests it is pretty hard to build a machine that will take an even, firm grip on a briquette. They are all open to the objection that they are liable to take uneven hold and make eccentric or cross-strains, thus destroying the value of the tests. From a study of a large number of tension and compression tests I have come to the conclusion that tension tests are less reliable than those in compression, besides not giving any data on the compression strength, with which we are, of course, concerned. I do not think there is a definite enough relation between tension and compression strength tests of cement for tensile tests to give any practical idea of the compressive strength of cement.

ELECTRICALLY OPERATED BRAKES FOR INDUSTRIAL PURPOSES*

By H. A. Steen

Non-Member

ABSTRACT OF PAPER

The paper treats of the theory, design and operation of electrically released industrial brakes. After a general introduction of the subject, the various classes of electro-responsive devices, both A. C. and D. C., are taken up and curves are shown. Formulae are given for the kinetic energy consumed by brakes, for the number of revolutions and time required for stopping, for the heat generated and the temperature rise due to the operation of brakes. The relative merits of various friction materials are discussed and the results of tests given. Several different types of brakes are critically examined and formulae and curves given. Twenty-five illustrations are shown.

DISCUSSION

Mr. H. D. James: After going over a paper the length of Mr. Steen's, which includes so much material, there is very little to be added in the way of special information, and I will attempt only to point out a few of the fundamental principles that underlie friction brakes. I believe these principles are applicable to brakes on railway trains as well as to brakes for stopping revolving machinery. In dealing with a brake of this character we should treat it as an engine transforming energy in the same way that we discuss the steam engine or electric motor. Let us consider a steam engine; the first question we ask is: "How does it perform its function of transforming the heat energy of the steam into kinetic energy?" In dealing with brakes we have about the reverse cycle. The

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brake changes kinetic energy into heat. The measure of the work done by the brake is the actual amount of heat absorbed and dissipated. We have the energy accelerating the machinery stored up in the moving parts of the machinery. When we bring those parts to rest we must change the kinetic energy into heat. The heat passes into the brake and is transmitted by the brake into the surrounding atmosphere. So that the work done by the brake is the transforming of one form of energy to another.

The next point is the adaptability of a brake to absorb this energy and transform it into heat and to dissipate it. The brake should have considerable specific absorption capacity, if we can call it that. The materials of which it is made must be capable of absorbing considerable energy if it is to be used as a stop brake so that the energy may be stored in a short time, probably two or three seconds, dissipating it in a longer period by radiation. If the brake, however, is used for retarding a falling body the energy is stored in the brake through a considerable period of time, and its absorbing capacity is not the principal function, but rather its ability to radiate heat continuously. So that when examining a brake from the standpoint of design we must first consider what the brake is to be used for.

The third function of a brake has still more to do with the details of design; namely it must be of such form or design that in converting kinetic into heat energy it is not destroyed. The friction materials must be as indestructible as can be secured for the purpose. They also must be well adapted for the absorption and radiation of heat. If any substance of an organic nature is used, the specific heat is very low and the mass is small, so that the storage capacity of such material is very limited. Most organic substances do not radiate and are not conductors of heat, with the result that they retard rather than assist the radiation of heat. Another difficulty with the organic substance seems to be its inability to withstand high temperatures. None of us would think of using organic materials for the friction surfaces of a brake on a

railroad car as we know they will not last. Those friction materials should be used which will not be injured by heat and which are cheap, as the service wears them out and we throw them away.

Another point to consider in a brake used for certain classes of industrial apparatus in shops, is that the retarding effort of the brake, the torque, will remain as nearly constant as consistent with the conditions of the design and the application. If the friction surfaces of a brake are run in oil the co-efficient of friction remains very constant. We all know the Weston disc brake. If, however, it is not desirable to have so complicated a piece of apparatus, the question is: What material can be used that will give a comparative degree of uniformity in friction? In my experience a metal comes nearer this than any other substance. An organic substance changes its co-efficient of friction rapidly if it is subject to severe heat. If it is worked with a lubricant the amount of lubricant on its surfaces determines its co-efficient of friction. Grit, dust and dirt interfere with this uniformity. If, however, a metallic substance is used and worked at a temperature which will vaporize any grease, oil or water that may accidentally get on the surface the co-efficient of friction will remain fairly uniform. It probably will not vary over 25 per cent.

In general, I believe these are the underlying principles in the selection of a friction brake. This, however, does not take into account special applications. For instance, there are places where lubricated leather will be the proper thing. These are but special applications of the general idea. In working upon this subject they have been the general principles that I have tried to bear in mind in applying friction surfaces for various purposes.

Mr. H. W. Stevenson: I have had considerable experience with disc type brakes. They formerly were designed with wooden plugs inserted in an iron disc which revolved against stationary bronze. I found that the surface was not

great enough to absorb the kinetic energy as quickly as required and I re-designed the brake making both bronze and iron discs solid, still maintaining the iron as the revolving disc. I noticed in Mr. Steen's paper the revolving disc was bronze and I wanted to know if there was any difference whether the bronze or the iron revolved.

THE AUTHOR: The breaking action will be the same with either the bronze or iron discs rotating. The rotating discs are usually bronze as they are smaller than the stationary discs and reasons of economy lead to the use of the more expensive metal in the lighter, rotating parts; further the bronze being the stronger metal it is better adapted to withstand the high stresses which occur in the rotating plates at the shaft.

MR. E. K. HILES: During the preparation of Mr. Steen's paper for publication a number of questions came up which were discussed with the author at that time, and I am going to ask him to answer a few of them again here.

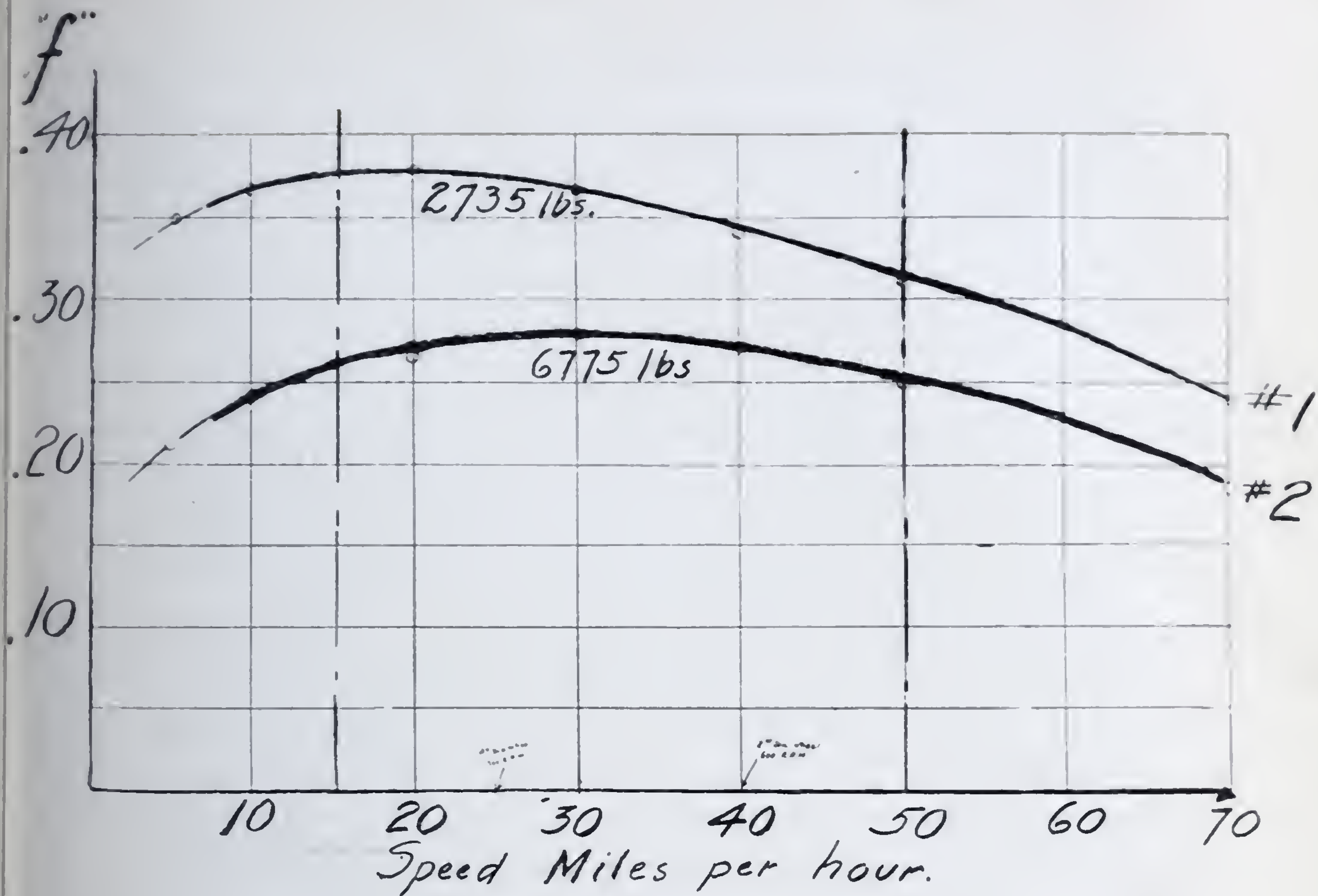
On page 396 the statement is made that the coefficient of friction of cast iron is dependent upon the speed. How does this condition influence the braking characteristics?

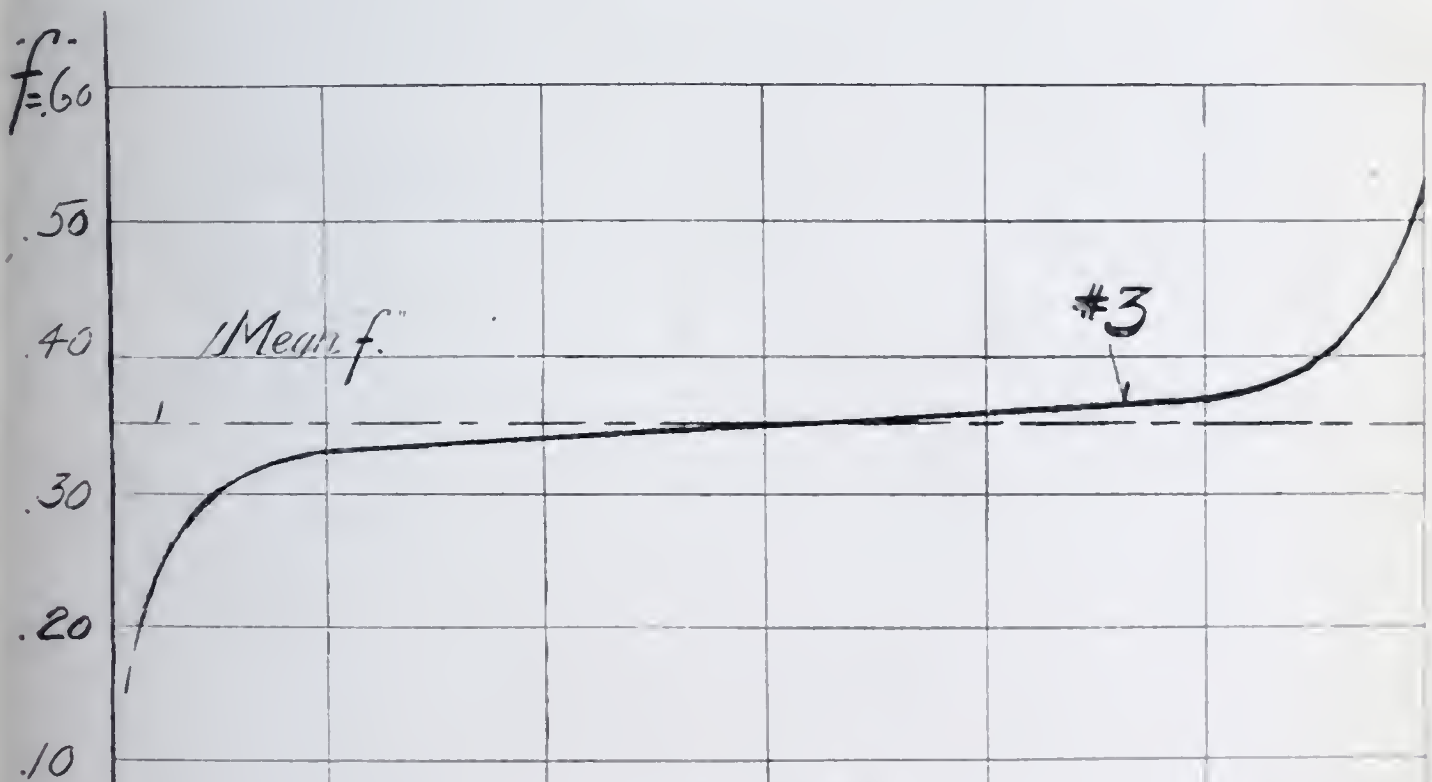
How do the shoe brakes, shown in Fig. 5, stand up under heavy continuous service, as regards their wearing qualities and their characteristics as to uniformity in action?

Referring to the curve of unit retarding moment in the latter part of the paper on page 405, one observes that the retarding force increases rapidly with the coefficient of friction, and it is, therefore, important to keep the coefficient of friction as uniform as possible to obtain uniform action in the brake. I want to ask Mr. Steen his opinion as to the influence of this feature, and how the new band brake, shown in Figs. 19 and 20, compares with the older types, such as that shown in Fig. 16?

THE AUTHOR: The results of tests made at Purdue University by Prof. R. A. Smart,* which are mentioned in my

* Now with the Westinghouse Electric & Mfg. Company, Pittsburgh.


"f"
.40
.30
.20
.10
2735 lbs.
6775 lbs
#1
#2
10
20
30
40
50
60
70
Speed Miles per hour.
Fig. 26.


"f"
.60
.50
.40
.30
.20
.10
Mean "f"
#3
Time
Stop.
Fig. 27.

paper on pages 395 and 396, are shown in Figs. 26 and 27. The brakes used in these tests were fitted with cast iron shoes the wheels carrying steel tires. The brakes shown in Fig. 5 to 8 and Fig. 18 to 20, are equipped with cast iron shoes and wheels. Therefore the results of the tests above referred to are not directly applicable to these brakes, but form, however, a fair basis for comparison, indicating the change of the coefficient of friction under different conditions of speed and pressure. The speeds, up to 70 miles per hour, are the peripheral speeds of the wheel at the instant of applying the brake. The coefficient of friction given is the mean during one stopping period.

Curve No. 1, Fig. 26, is for a shoe pressure of 2735 lb., and curve No. 2 for 6775 lb. Curve No. 1 approaches most nearly the conditions met with in industrial brakes. The peripheral speed varies from 15 to 50 mi. per hr. for these brakes, and it can be seen from the curves that the mean coefficient of friction "*f*" maintains a high value between these limits. The variation of "*f*" (or the retarding torque) during one stopping period varies approximately as shown in curve No. 3, Fig. 27.

The torque rises rapidly after the application of the brake until a certain point is reached, after which the increase is more gradual. When the wheel slows down toward the end of the braking period the torque rises to approximately 1½ times the mean torque. This means that the brake shoes grip the wheel, when applied, without much of shock, When stopping, a tight gripping takes place, and the static torque of the brake is much larger than the mean torque of a braking period.

As to the wearing qualities of shoe brakes shown in Fig. 5 to 8, I will refer to one case where a 75 h. p. brake of this type was used for the screwdown of a 35 in. blooming mill, a very hard service indeed.

After four months of continuous operation the shoes and wheel showed very little wear, and all parts were in perfect condition. In this case very quick and accurate action of the

brake was necessary for adjusting the rolls and the clearance between wheel and shoes was, therefore, adjusted to 1/50 in. approximately, making the necessary travel of the magnet core only ½ in., effecting a quick action of the magnet plunger.

The new band brake, Fig. 18 to 20, has soft cast iron friction surfaces, a radical departure in band brakes. The brake is not lubricated. No appreciable change in the structure of the surfaces or of the coefficient of friction "*f*" takes place if the right pressure is applied. Oil or water which might accidentally appear, would be rapidly burned off.

The brake, Fig. 16, generally has a wooden lining and is lubricated. The "*f*" varies greatly with the kind and amount of lubricant, and the amount cannot be controlled. It also varies with the conditions of the surfaces, which change with wear and heating. A band brake of this type therefore, has a very uncertain retarding torque. The strains on the brake parts and shaft vary greatly and an excessive strain can be expected at any time. As a consequence the brake and shaft must be dimensioned much heavier than for the normal torque. Another fact which makes this brake more bulky and the necessary applied force larger, is that the lubrication decreases "*f*." If "*f*" is decreased from 0.30 to 0.20, a liberal assumption, the applied force must be doubled for the same torque.

Considering that this brake inherently gives only one-seventh of the torque of the new brake, the advantage of the new operating mechanism and cast iron lining can readily be understood. The comparison betwen the two brakes, p. 401 and 402, Fig. 15 and 16 (the comparison also holds good for Fig. 15 and 18), is much too liberal for the type, Fig. 18, on account of the frictional qualities (the value and constancy of "*f*") not being compared, the same "*f*" for both types being assumed.

G. E. Flanagan: I would like to ask if there are not in use brakes that operate by an electrically retarding influence, somewhat the reverse to the action in an induction motor? There are such things as induction clutches for driving ma-

chinery and I believe the same principle has been applied to brakes for retarding the fall of a load.

THE AUTHOR: The trouble with these brakes is that current is required for braking, which prevents their use for general application. Eddy current brakes are used for street car work in connection with dynamic braking, but I do not know of any in use for industrial purposes.

MR. J. L. KLINDWORTH: I would like to know whether the shoe is hard cast iron and the wheel very soft, also whether the heels on the shoes wear rapidly.

THE AUTHOR: The wheel and shoes are both of soft iron. The brakes of the type shown in Fig. 8 wear very slowly and evenly indeed. The adjustments necessary are very few.

MR. BRENT WILEY: There is one feature in the brake under discussion which has given very satisfactory results, and that is the gradual manner in which the retarding force is applied so that the shaft does not take the retarding force as a shock. That is one of the particularly good points in a brake of this kind and one in which the old type of band brake was at fault as in that the load was suddenly applied. This is one of the practical points that have been brought out in all references to experiences we have had in the field.

MR. W. O. BROSIUS: I would like to ask Mr. Steen about how quick they figure on stopping a motor running full speed, not driving any machinery, with just the momentum of the armature behind it. About how many turns would a 75 h. p. 600 r. p. m. motor make before it comes to a dead stop from full speed ahead.

THE AUTHOR: It depends very much on the brake, the band brake, Fig. 20, stopped the motor in about three or four revolutions I should say. Considering the size and weight of the brake this result is not obtainable in other reversible band or shoe brakes.

Mr. H. D. James: It depends very much on the motor shaft. About five or six revolutions is as quick as is usually safe. In a motor properly designed for a quicker stop it could be accomplished in considerably less time. Practically all the energy the brake absorbs is that of the revolving element of the motor. The load itself super-imposes a fixed torque which decreases the available torque the brake has to stop the motor. If, for example, a motor running five or six hundred r. p. m. with any reasonable amount of stored energy and it is stopped under five or six revolutions, the brake exerts rather a severe strain on the motor machinery, particularly on the gears. Brakes can be made to stop a motor in two or three revolutions if the motor is strong enough.

Mr. Lee C. Moore: I would like to ask the gentlemen what experience they have had with an automatic or self-acting brake. I have had some experience with self-acting inclined planes. I learned a long time ago that accidents were largely due to the operator not being quick enough with his brake. Some years ago I had occasion to build a heavy plant and it occurred to me to reverse the operation and build it with the brake always applied so that the operator had to lift the brake to release it, and I have never had a run away on that plane. It is a pretty heavy incline, 35 per cent grade and about 1800 ft. long. The device was arranged by putting weights on each brake leaf heavy enough to exert the full power of the brake. The method of operation is by means of a wheel lifting these two weights, which, of course, releases the brake bands and the trip starts down the hill. If it gets to going too fast the weights are lowered a little. In other words the weights set the brake; all the operator does is to release the brake. The operator has to exert a force constantly to overcome the weight, and if he releases the weight the brake would set automatically. The difference between the brake band when set and released is very little. For instance, the brake bands were six feet in diameter and the length of the weight lever releasing those brakes was four feet, lifting the weight six inches would release both brakes.

Mr. E. K. Hiles: I think that same idea is exemplified in Mr. Steen's paper in the band brake which has a cast iron sleeve split along one element, which springs away slightly from the wheel surface, and I judge that spring is very little. How much is it, Mr. Steen?

The Author: The clearance necessary is not over 1/32 in. and often less than that. This is one of the great advantages of this brake. It means a small travel for the magnet; and in turn a small magnet with less current; and greater efficiency all along.

Mr. Lee C. Moore: That is exactly what I was trying to get at. I venture to say if you bored your band 1/64 in. larger in diameter than your wheel and supported it in such manner that its own weight would not carry it down on the wheel surface, that it will release your wheel every time.

The Author: I recall a brake about two feet in diameter for which the band was bored 1/8 in. larger in diameter, giving $\frac{1}{16}$ in. clearance all around. With a wheel six feet in diameter, I would bore it at least $\frac{3}{16}$ in. larger in diameter. After the band is properly adjusted by set screws the actual clearance is reduced to about 1/32 in. all around.

Mr. G. E. Flanagan: The question of automatically applied brakes suggests a certain relation between safeties of elevators and shoes on a brake. There are some safeties on elevators in which the shoes have a kind of planing action on wooden guides. I think Mr. James can tell us something on that subject.

Mr. H. D. James: Mr. Flanagan refers to a form of brake known as car safeties attached to the frame and generally applied by centrifugal action of a governor at over speed. One form of clutch consists of a series of diamond-pointed knives that cut into an iron rail. That does not resemble our brake as closely as the form of safety brake which grips the rail with a wedge action. The rail consists of a steel T and the safety

grips it like a pair of scissors; it is driven by a tremendous force so that in reality it cuts into the metal, although not appreciably. It differs from the ordinary reversing brake in that if applied very often it would result in the destruction of the guides. It is something to be applied only on occasions of emergency.

There is one point that Professor Smart's experiments brings out that is interesting. Referring to curves, No. 1 and 2. Fig. 26, if the zero speed and the very high speed is considered it is noticed that shortly after starting the friction drops off from static friction to running friction and continues along at about a mean value until quite a high speed is reached, when the friction decreases rapidly. I have been considering this in connection with run-away trolley car accidents; when once the car is going rapidly down an incline it is pretty hard to stop it with a brake. Even with heavy cars there does not seem to be the necessary adhesion to bring it to rest. It must be that there is, with two friction surfaces rubbing together, as Professor Smart suggests, a rolling of the molecules. The surfaces seem to be self-lubricating so that two surfaces traveling beyond a certain rate of speed do not exert much friction upon each other. We have all had experience in trying to stop a piece of apparatus after it has got beyond a certain speed, the brake that usually is effective does not stop it under these conditions. After an elevator car has attained a certain speed there is only one way to stop it, and that is to cut into the guide sufficiently to make it stop.

Mr. G. E. Flanagan: It seems to be definitely established that cast iron against cast iron is the thing in brakes of the types under consideration. But perhaps there is some further word to be said on this point. There may be brakes in use composed of two metals, one for strength and the other for friction qualities against the surface of the revolving part.

Mr. H. D. James: In regard to the question of friction surfaces I do not think the last word has been said by a good deal. The experiments and such other published data as Mr.

Steen has had access to indicates that cast iron on cast iron gives the best results. It is perfectly possible that other metals may be produced which may be very much better. This merely represents the information that certain of us have been able to get up to date.

MR. E. K. HILES: In bringing out the fact that cast iron on cast iron is one of the best arrangements of material for friction purposes, it is interesting to note that the same arrangement is also one of the best for avoiding friction. Many years ago Mr. Charles T. Porter built a high speed engine with a cast iron shaft running in cast iron bearings which soon took on a highly glazed, very hard surface and showed very little friction. It is worthy of note that the same material, by merely varying the pressure, will exhibit such antithetic properties. Using cast iron as a non-friction material the pressure is kept low enough to permit it to glaze, using it as a friction material in a brake sufficient pressure must be used to cut the glaze, or prevent its formation, without seriously scoring the cast iron.

MR. LEE C. MOORE: What experience has been had using wrot iron against cast iron in brakes?

MR. H. D. JAMES: We used cast steel on cast iron with fair results. The wear for the same amount of work was considerably more than with cast iron on cast iron. When we came to a fibrous material it seemed to disappear in chunks. It is the granular form of the metal that seems to give it long life and still the proper action. Of course, there is a fine powder that generally gathers at the brake. The tests we made were with a 13 in. wheel used as a stop brake for a heavy armature, and it was operated about every six seconds, 10 or 12 hours a day for about six months with some accumulation of dust, the cast iron wheel being reduced about $\frac{1}{16}$ in. in diameter. The shoes wore much faster, of course. We lined the shoes with sheet steel and they cut the wheel down rapidly. We lined them with bronze plugs which cut groves in the wheel. We tried lignum vitae which gave good action until it burned up. Certain shoes lined with babbitt metal have been

used by one of the crane builders, but I think that babbitt has a tendency to flow if it is worked hard. It seems that the granular nature of cast iron is the real reason for its successful operation.

Mr. Stevenson spoke about bronze on iron. I do not believe bronze is very good and I am sure it is expensive to grind up in that way. For a brake working under these conditions I do not believe any fibrous material is good. Discs run under oil are often made of fibrous material. The disc is generally sheet steel, and I believe they do use bronze. But where there is considerable wear and something cheap is wanted, cast iron seems to fill the bill pretty well, and although other compounds may be evolved that work better, I doubt if we will get anything that will be as commercially suitable as any commercial grade of cast iron. Common iron is not quite as good as a uniform grade of soft cast iron, but it is cheap and it works well.

Tests on a brake are pretty hard to make with more than a certain degree of accurcay, without expensive apparatus to record results. To test the constancy of friction, the motor was used to drive the platen of a planer running at constant speed, and a bar of iron was placed in the V of the back grooved way of the planer so that when the bed came up on the high speed stroke it would barely touch the bar. Observation showed that there was not $\frac{1}{16}$ in. variation in the point of stoppage of the planer bed. Of course, the gear ratio between the motor and the bed of the planer was considerable, but it will give an idea of the commercial accuracy with which we measured the variation in friction. Another test to determine the uniform character of the friction was to set the brake and drive the motor at a certain fixed speed and measure the electrical input. If the friction surfaces varied, either the speed of the motor would vary or the electrical input wiuld have to vary. We found that there was not a marked difference in the friction. We did, however, notice that at the higher speeds at which this brake was driven the coefficient of friction dropped off somewhat as indicated by the curves shown in

Fig. 26. These tests were not on an elaborate scale at all, they were entirely commercial, made in a rough commercial way, because the results sought were intended to be used in selling a commercial product.

THE AUTHOR: I think that the following reasoning may explain the dropping off and variation of the torque, besides the decrease of the coefficient of friction at higher speed. After the cool shoes are applied the tips heat and tend to straighten out and separate slightly from the wheel surface. The pressure per unit area will, therefore, be greater at the middle of the shoe. The pressure on the wheel decreases on account of the reduced wedging action for smaller arcs of pressure surface, and the torque as a consequence decreases also. After a while the ends of the shoes again engage with the wheel as they cool down and the pressure and torque, therefore, approach their original values. This may explain the decrease and small fluctuations in the current input of a motor loaded with a brake.

In conclusion I wish to express my thanks to Mr. H. D. James for the valuable information placed at my disposal, and to the Secretary of your Society for the interest taken in my paper in its final preparation for the Proceedings. I wish further to make acknowledgement to those manufacturers who have furnished descriptions of many interesting designs.

[NOTE: On page 392 in original paper make value of

$E_2 = 0.000\ 001\ 19\ W_2\ R_g^2\ (\text{r. p. m.})^2$]

THE ENGINEER AND THE ENGINEERS' SOCIETY

By G. E. Flanagan

The engineer is an individual who is constantly striving to increase the efficiency of all the forces at his command; and to him all things must justify their existence by proving their usefulness, in some form and degree, in the service of mankind. This is true, not only of the material objects of which he finds the universe composed, but the engineer is very apt to demand the same essential usefulness from all human institutions to which he gives his attention; and, therefore, a society such as this, established by engineers, must stand or fall by submission to the same crucial test.

Let us consider briefly what the engineer has done and is doing, for it is by his works that he is to be known; and turn where we will we are confronted by monumental evidence of his skill and knowledge.

Probably the first constructive work performed by man was in the formation of habitations to protect himself from the elements; the next, in all likelihood, the throwing of a log across a stream in imitation of the work of the winds, which doubtless thus provided the first bridges.

Ages before the erection of the pyramids, or the carving of the rock tombs and temples, some mechanical genius discovered the principle of the lever; or, more likely, applied it with but little more than a most shadowy understanding of its principles, and certainly without even the most remote conception of how future engineers would make use of it in a myriad of ingenious contrivances. In just what manner the problems which confronted the builders of the pyramids were overcome we do not know. Large masses must have been transported with what to us would seem very inadequate

Address of retiring Chairman, delivered before the Mechanical Section, February 2, and published in the March, 1909, Proceedings.

means, except that there was a practically unlimited supply of human and animal labor, and methods existed of forcing it to the utmost effort. It has been suggested that, as the pyramids grew in height, a sloping earth roadway was built, up which the enormous weights of stone were dragged by main strength, with the assistance of rollers, another mechanical device of which great use has been made since its first inception, and never more than at the present time. Mighty structures were raised by piling stones one upon another, Cyclopean walls were built and openings spanned by monolithic lintels put in place by prodigious labor, until science came and showed what could be done with properly shaped stones forming the arch, and the art of building took one of its greatest steps forward.

The simple rectangular beam was found to be a very wasteful form, and one in which the weight of the material used soon overtaxed its strength as the structures increased in size, and the engineer improved upon it by putting the material where it would do more good, in the shape of flanges connected by a thin web, thus using the material to much greater advantage. This form being still unsuited to constructions of the greatest magnitude, the open latticed girder was introduced, and the principle of modern trussed work was envolved, with a still further increase in that efficiency in the use of material for which the engineer is always seeking. Trussed bridges, requiring extensive falsework for their erection, have often called for the exercise of the best engineering talent in their construction, aside from that demanded by the design of the bridge proper; and then came the cantilever type of bridge truss which is self-supporting as erected, the parts first placed in position carrying upon themselves a traveler for handling those which follow.

The ancients built aqueducts to convey water, the moderns do it in tubes or closed conduits; the former were magnificent structures in themselves, the latter of greater credit as a more perfect adaption of means to an end, and this has been offered as the characteristic of the capable engineer that he

can do with small means what another may accomplish with greater. To drain the waters of Lake Fucino in the days when the Romans held their sway, about thirty thousand men worked for eleven years, driving a tunnel some three and one-half miles long, and even then the undertaking was not entirely successful. The modern engineer with his equipment of machinery and high explosives, would consider the task an easy one in much less time and with perhaps one per cent of the men.

Tunnels through the hills and under rivers, subways beneath the various activities of the city's life, with speedy trains transporting its people to and fro in the ceaseless round of daily cares or business which constitute the mainspring of modern progress. How many, even of those engaged in some branch of this mighty work, realize the marvelous advances made in one short hundred years. When men can drive a tunnel twelve miles in length beneath the mountains, and, working from each end, have the lines meet within a distance of less than one foot, and when they can build out from either side of a mountain gorge slender looking structures that meet and form a bridge over which many hundred tons of freight and passengers are so swifltly carried, it might seem that human achievement could go no further. But perhaps all this pales before the marvelous aggregation of many minor marvels which center in that wonderful unit the ocean steamship. A floating palace which is no small fraction of a mile in length, and in which the population of a small town may pass from continent to continent in the brief space of a few days, meanwhile enjoying all the comforts of their homes upon the land. is what modern engineers place at the service of those who wish to travel; and all this has been evolved from the floating log with which primitive man assisted himself and his belongings across a stream. But after all it is probably not the peaceful steamer which must be looked upon as the most strikingly concentrated example of all that man can do. Unfortunately we have in the battleship of the present day a unit by which the greatest of those which embody the arts

of peace is outclassed, and this with all its mighty engines of destruction is perhaps the perfection of human attainment, and at the same time the most mournful example of misplaced energy, showing that the intellectual and moral forces in the world at large have not kept the pace set by our industrial advances. But while the engineer may well regret to see the culmination of his greatest efforts embodied in an engine of warfare, it is nevertheless indisputably true that the trend of his inventions is toward the extension of the arts of commerce and trade, thus bringing the nations closer together and reducing the frequency of destructive conflicts.

Having attained such mastery of the earth and sea, man looks to the air for other fields to conquer, and the past 12 months marks the most signal progress that has yet been made in this direction. Ships of the two distinct types, the one of which is lighter than air and rises by reason of its buoyancy, and the other which attains its flight by purely mechanical means, have sailed above the earth, and although the leaders in each of these lines of effort met with accident in the operation of their machines, this did not occur until their possibilities had been demonstrated and the path of future success had been pointed out.

The Panama Canal, which will sever the parts of this continent and provide a water way between the two great oceans, is not a recent enterprise, but it has recently been taken up under conditions that insure its early completion; and no one now doubts that ere many years have elapsed it will be conferring its benefits upon the world. Back of this undertaking now are the resources and the determination necessary to insure its being brought to a successful conclusion. In the conformation of the new world, nature seems to have offered to man her defiance to join the waters if he dare. The temptation to do so has been strongly felt, but it was only by the aid of modern engineering skill that the problems could be successfully grappled with.

Having devised means for projecting himself with speed over the earth and over the sea, and to some extent through

the air, man finds the earth too small for him; that is the favorably located spots such as the business portions of many cities are too small for his purposes; and to overcome this difficulty the engineer designed the tall office buildings, some of which have grown to such a height that they may each be considered as a small city stood upon end, with elevators of such capacity speeding from floor to floor, that it has been said that more people are carried vertically in a great city than are transported in a horizontal direction.

Aside from the great features of bridges and tunnels the modern railway is an institution involving hundreds of engineering problems which have been solved in a manner evidencing that, let the difficulty be howsoever great, if it be only of sufficient importance a satisfactory solution will be forthcoming. Few of us realize the part which the railways play in our lives, but some conception may be had when we are told that the ownership of the railways means the control of about 16 per cent of the wealth of the nation. But for these slender threads of steel that weave a network over the land, much of the onward march of civilization would have made comparatively halting progress.

Looking backward, the engineer views with regret the almost wanton destruction of our once boundless forests and the waste from inefficient use of our valuable mineral fuels; and for the future plans more careful use of both of these forms of stored up energy. The conservative use of fuel, and the capture of by-products heretofore wasted in many forms of combustion, has been an important study in the recent past, and will be for the immediate future. For our more remote posterity we look with trust upon the plan of transforming part of daily beams of radiant energy from our great luminary by some form of solar motor, which, probably with the assistance of long distance electrical transmission, will aid in compelling the desert and waste spaces of the earth into the service of mankind, even as we do at the present time with the water powers of the world. With the exhaustion of the world's store of fuel will come the necessity of impressing nature's constantly active

forces into the service of the human race, and the chief reliance of the future must doubtless be upon rapidly grown vegetable fuel, the yield of which may be increased by scientific fertilization of the ground. In the manufacture of alcohol from vegetation, a means exists of obtaining fuel from plants without impoverishing the soil, as all the compounds necessary to its continued fertilization may be returned to it.

In time gone by the engineer was classed as "civil" in contradistinction to those engaged in the military arm of the government service, the meaning merely being civilian engineer. Today this title describes those who pursue certain branches which join in with the broad stream of engineering, and like qualifying words are applied to others, such as mechanical, electrical, mining, metallurgical, etc. But there has been a tendency among civil engineers to regard theirs as the important branch of the profession, while those with mechanical training have considered that by reason of the varied requirements of their work the distinction more fairly belongs to them. Such a question should never be permitted to arise. The capable man in any of these special lines knows much of many others, and finds exercise for all the mental force that ever existed within the compass of one human intellect.

Long past is the age of stone and the age of bronze. The present has been termed the "age of steel," and there are those who say we are now entering upon the age of concrete. Neither the present nor what we may guess of the future can be restricted within any such narrow bounds. Rather would we say, this is the age of the engineer whose genius combines them all.

The story is told of a young artist, who, standing before the work of a master, impulsively exclaimed: "And I, too, am a painter!" Has not the engineer much greater cause to feel the importance of his profession, and remember that he assists in setting in operation the forces by which the world moves forward. Listen to the ceaseless throbbing of some monster engine and realize the mighty forces thus in action

for the benefit of, and in response to the creative intellect of mankind, and know that it is the engineer who has done this work. Stand upon the mountain side, and look down into the valley where sweeps the broad river in its silent course to rejoin the waters of old ocean from whence it came, and note the graceful structure of steel which spans the gorge and affords safe passage to the valuable freights carried by our modern trains, and is crossed at high speed by those bearing passengers who readily entrust their lives to the structures evolved by the skill of the engineer. Who can contemplate the vast advances evidenced by the progress of only the last fifty years, and realizing that they add breadth and security to the foundations upon which our civilization rests, fail to feel a pride that he has had a share, however small, in bringing about results which are destined to enhance the welfare of mankind to the end of time.

If credit is due to him who has made two blades of grass grow where one grew before, then let the engineer step forward. It is he who has done this beyond the measure of all others, and has himself benefited by the doing of it. He works in a field that is wide, and has his mental scope correspondingly enlarged; and taking a proper pride in his work, is saved from the indulgence in a narrow conceit of himself. He gives to the world his best because the constructive spirit has been awakened within him; it is this work which his hand has found to do, and he accepts such reward as the world has seen fit to offer.

The surprising developments of the last score of years in the line of electrical engineering, are the fitting fruits of the half century of mechanical progress which preceded it. In all its essentials the steam engine was a most complete invention when it made its advent before the world; at least its principles as we understand them today were very fully comprehended by James Watt, but the means were not at hand for constructing it with sufficient refinement, and at a cost to render it commercially practicable, and these means had to be developed along with the engine itself. When the electric generator and motor were born, the facilities existed for their

construction with any required degree of precision, and the requirements of the designer could be met to the fullest extent. They were free to ask for what they wanted and it was at once forthcoming. This left them at liberty to design solely with a view to efficiency and with but little thought as to any difficulties of construction. There was thus presented to the electrical engineers an opportunity of unparalleled scope and very nobly have they taken advantage of it, and given to the world results strictly in keeping with the vastness of the field which opened for them.

While the civil and mechanical engineers have joined the oceans by means of canals, and brought remote parts of the earth within easy reach by means of railways, their brothers in the field of electricity have wrought marvels, and are still reaching out and accomplishing the hitherto impossible. In view of what has been done the imagination halts in its effort to conjure what may follow. It was not enough that they should girdle the earth with wires along which intelligence may be flashed with lightning speed, that over the bottom of the sea their cables should stretch from land to land, but now their signals may pass, by the magic of wireless telegraphy, to and from the ship in the midst of the waters. Nor is this the end, electric waves, varying in amplitude with the inflections of the spoken word, traverse the infinite space, and at the receiving station cause the reproduction of the same vocal sounds and wireless telephony announces its coming to the world.

The electrical engineer might well rest satisfied with all that his skill has wrought; but to the future still he looks, and what that dim vista has yet in store, and what may full soon unfold, none of us may say.

THE ENGINEERS' SOCIETY

The engineer must be a man highly educated along the lines of his profession, and broad enough to realize his relationship to the world at large; and it is in the furtherance of this higher education among its members, that this Society, and other similar bodies, find the field of greatest usefulness.

The greatest and best of our engineering colleges cannot turn out the engineer fully equipped for the large work which he may be called upon to do. In the making of an engineer, college training will do much, but it cannot do all; and the work of the school must be supplemented by other influences, not the least of which is the technical society, and the valuable information which it places within the reach of its members.

In the published volumes of its Proceedings, the Society gives to the world the benefit of many and varied experiences; but to its own members it gives this and something besides. and that is the benefit of the personal influence of its members upon each other. This benefit can only be secured in its fullest measure by those who not only belong to the organization, but also attend its meetings and take an active part in the work it is doing. The papers presented, together with the bulk of the discussion which they evoke, eventually appear in the Proceedings where each may read for himself; but there is a difference between the spoken word and that read from the cold page of a book; they both have their place in educating the mind, and that of the one can never be entirely supplied by the other. The personality of the speaker awakens our mental processes in a manner somewhat different from the more vague influence exerted by an author whom one has never seen.

Moreover, the engineer, the man who deals so strenuously with matter and its immutable laws, is not brought sufficiently into contact with that less stable and more mysterious compound known as human nature; and this is a want which the fellowship of the members tends to supply. Reading, too, is often pursued along somewhat narrow lines, the subjects chosen are very likely to be only those of immediate interest, while a principal merit of the Society's meetings lies in the great variety of the subjects presented, which often awaken an interest that would not otherwise have been felt. A lively discussion in itself compels attention, and the knowledge thus attained is acquired with a minimum of effort. The problems of engineering are continually becoming more numerous and varied, and the Society as an aid to the attainment of an up to date knowledge is a means which the progressive man

cannot well afford to neglect. Technical societies keep us in touch with the work of each other, and to fully appreciate what others have done is in itself a liberal education.

By reason of the papers presented, and the discussions which follow them, ideas are advanced and information placed upon record, which, without its intervention, would have been lost to the world. The volumes of our Proceedings have formed an important contribution to engineering literature for nearly 30 years, and it must be remembered that this printed record contains only a mere suggestion of the work done by the membership during that period. To the credit of our members stand some of the most monumental of recent works in the field of steam and electrical engineering, blast furnace and steel works construction, and most other lines of endeavor have received a share of attention, while even the far-off stars have been made to come more closely to us.

Such is the story of the past; what the future will bring forth is a tale which may not yet be told. The time is certainly approaching when the engineer will become more active in the work of the world aside from his activity along his chosen line; that is he must become in a much greater degree than at present what is known as a man of affairs, and have a larger part in the management of great enterprises; and in that day he will receive a fuller recognition and a greater recompense. At present he works in response to his inner promptings, and not because the world has made the reward an especially attractive one. As yet he exists as so new a development that his value is but little understood; he has not yet come into his own. It is his work which makes possible that of others who benefit by his labor, and who, while less essential to industrial progress, are so circumstanced as to receive a larger share of its rewards, and this is reason sufficient for the existence of this Society, and that of others of a similar character. Every well organized Society is a force that operates, not only for the advancement of its own members, but of all others who occupy positions in the field which it represents, and becomes a factor of increasing importance in the advancement of human progress.

MEMOIR

WILLIAM ROBERT BROWNE.

Born at Greensburg, Pa., August 4, 1846.

Died September 3, 1908.

Mr. Browne was a Charter Member of the Society.

He received his early education in the public schools of Pittsburgh and Duff's College. Deciding upon an engineering career he perfected himself by private tutoring, and in 1868 he entered the office of R. L. McCully, Engineer and Surveyor, as a student, later becoming Assistant Engineer in the same office, which position he held until 1876, when he took a position in the Engineering Department of the City of Pittsburgh, and for 27 years filled various engineering positions, advancing to City Engineer, which position he held until the Engineering Department was divided, Mr. Browne being appointed Superintendent of the Bureau of Engineering and Surveys, continuing in this position until he retired from the service of the city on April 1, 1903, to form the engineering firm of Browne & Layton, Engineers, Pittsburgh, and remained as senior member of this firm until his death.

Mr. Browne was a grandson of the Rev. Robert Bruce, D.D,. first president and organizer of the Western University of Pennsylvania, and a nephew of David D., and George Bruce, of Pittsburgh.

He was an ardent student of science, contributing many articles on municipal work, having been identified with practically all municipal improvements of this city, and it is doubtful if any engineer had a more vivid or greater mental capacity than Mr. Browne, it being a matter of comment that he could give almost any bench mark or city record from memory.

He was a member of the American Society of Civil Engineers, Engineers' Society of Western Pennsylvania and a number of other scientific bodies.

MEMOIR

HENRY AIKEN.

Born August 2, 1843, in Belfast, Ireland.

Died Decemder 11, 1908, at his home, 5526 Fifth Avenue, Pittsburgh.

Mr. Aiken's membership in the Society dates from 1880, the year of the Society's original charter.

His parents brought him to this country when he was a child and his home has always been in this city except for a short time spent in Philadelphia. He offered himself as a volunteer in the early days of the Civil War and took part in many battles, being wounded a number of times.

Mr. Aiken was one of the most progressive and successful of those engineers who have arisen in response to the demands of the iron and steel industries. He was ever a man of advanced ideas in the engineering world and many of his designs and improved methods which were regarded as distinct innovations nearly a quarter of a century ago, are considered the best practice at the present time. His work in developing mechanical equipment for steel works is still in evidence in the large mills of Pittsburgh and other steel centers. His marked ability was asserted in every department of steel works construction from the mechanical details to the planning of complete plants designed for economic production.

In addition to his practice as a consulting engineer, Mr. Aiken operated a large manufacturing plant at McCandless Avenue and Fifty-fourth Street.

Mr. Aiken leaves a widow, a daughter, Miss Nellie C., and one brother, James H. Aiken.

CAR WHEEL FORGING

AND CONDITIONS OF STEEL FOR HIGH SERVICE

By Jas. H. Baker†

From 600 000 to 1 000 000 tons of car wheels are made per year. A forged steel wheel era is commencing. I give you what I know and believe on this subject. I have no interest, nor have you, in anything but the truth, or at least the nearest approach to it that we can make. I am glad to avail myself of what others have done, which I have learned from books and otherwise; but for a real foundation I must fall back on my experience, in which hand blacksmithing was quite a factor. If it were customary to dedicate these papers I would inscribe this one to a dear old man who taught me while I stood on a platform in order to reach up to the anvil. I shall have to omit, or at most touch but briefly, some of the points announced for this paper, and as there is work enough in designing a wheel plant to occupy a corps of engineers for months, it is impossible for me to go into details. Then, too, there are things which, for one reason or another, are confidential, as in the case of plans shown to me as personal favors, and I cannot in common courtesy speak of them. There is a saying about the rejected stone becoming the head of the corner. Many stocks and inventions have gone begging and then become most valuable. I do not pretend to say whether either of the methods touched on in this paper will become the accepted practice, but certainly the best in this matter has not been reached yet. I shall make some repetitions of what I have written formerly. There are plenty of cases in which things had to be repeated again and again before progress could be made. I have no doubt but that many of you have had the same experience. For instance, I worked

Presented at the regular meeting of the Society, March 16, 1909, and published in the April Proceedings.

† Forging Engineer, Commonwealth Building, Pittsburgh.

years before I could get a high carbon knuckle pin for car couplers into general use, though I was just as certain ten years ago that it was the best, as I am now when the roads are accepting it.

Fig. 2 shows a standard brake rod jaw, and Fig. 1 the improved "Baker" design. Look at the sections in Fig. 3, where nearly four square inches are used to pull a section of about six-tenths of a square inch, and tell me, if you can, why it took years to get the improved one into general use. I should say that I now have no interest in the sale of these articles.

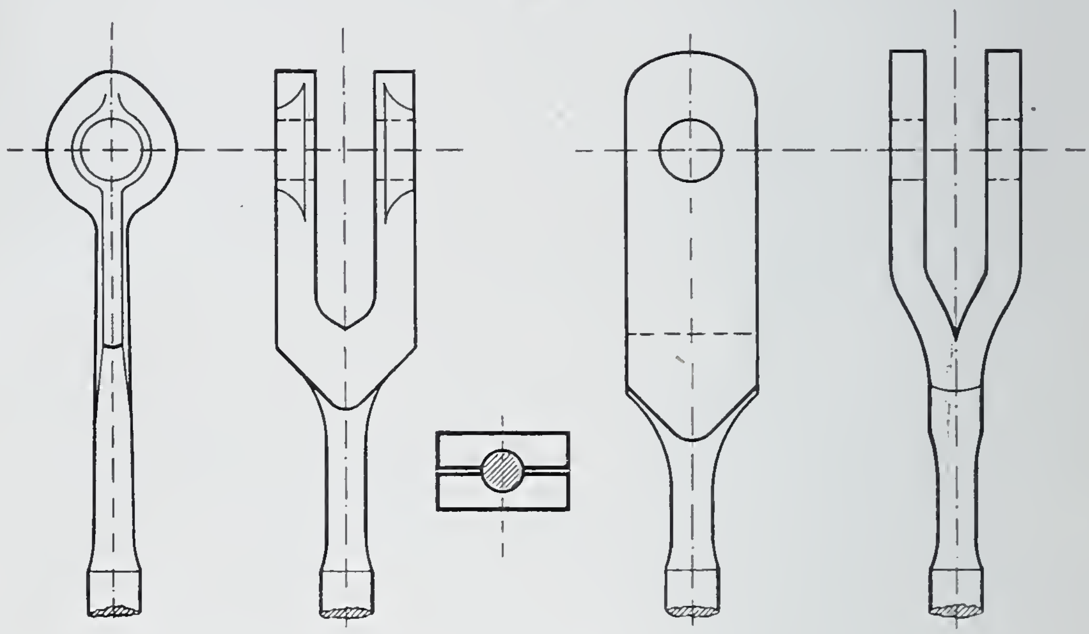


Fig. 1. Fig. 3 Fig. 2

Quality comes first; therefore, I take up the kind and condition of steel first, because this should be determined, and then suitable provision made for the most economical way of forging this steel. I do not take up alloy steels, as the makers of these are better qualified than I to do this. In an article running into such large tonnage as car wheels it is highly desirable that the lowest priced, in other words, regular commercial kinds of steel should be used. I believe that carefully made O. H. steel will answer every requirement if rightly forged and properly treated. I would rather trust this than higher priced steel which had not been put into proper condition. For instance the elastic tensile limit of a given steel suitable for wheels, can easily be doubled, and at the same

time the steel made far more reliable against snapping. The question of steel treatment and how to apply it is very important. I know it is easy to make figures, and yet I trust that a rather long experience in forging and treating steel will be some reason for this paper.

As to the composition of steel for wheels, some were made at first of 0.60 to 0.70 carbon, later 0.60 to 0.80 was used and quite recently 0.65 to 0.85 with manganese about the same. We shall go still higher in hardness and strength. This can be done by higher carbon, and safety assured by toughening the steel after the wheel has been rolled, or by hardening and toughening steel of the present composition. It is foolishness to expect the best service without proper treatment of the steel after the mechanical work on it is done. I speak now of conditions in steel rather than of how to produce them. There is something to be learned regarding how far certain conditions are to be maintained in relation to other conditions, such, for instance, as ultimate strength, elastic limit, reduction of area, hardness, size of grain, etc. There are many things in which we do not demand some of these qualifications, and the higher the class of some articles the less attention we pay to some of these conditions, because the essential value is all, or nearly all in other requisites. We hardly think of reduction of area and elongation in connection with the steel in a razor, but, on the other hand, we think a great deal of elongation in chains. The boy as you remember had many reasons to give why his father could not come to work. The first of these was that he was dead, and, of course, there was no use for any further reasons. So, with certain qualities in a given article assured, we need not trouble about others. What is the use of calling for 40 to 50 per cent reduction of area in steel for an article which is put out of service if bent the least bit. Far better to trade a portion of this quality for additional strength. In other articles the reverse of this is true. It is not how much steel will bend, or bend and rebend, but the real significance is in how long or how many times it will resist a given strain. In other cases, for instance, that of resistance to abrasion, we may largely center our attention on hardness and

the size of crystals. Other things being equal, a different hardness of the surfaces working against each other seems desirable. I take it as indisputable that the central portion of ingots should never enter the rim or tread of the wheels, and I believe the years to come will bear me out.

Coming now to making the wheels, perhaps I should undertake to tell what I consider the best method of forging wheels. But you may be pleased to have different methods described and the matter left for your consideration. Therefore, I take up the most important of these briefly. Since present manufacturers are free to make changes if desirable, there can be no harm in incidentally pointing out what I consider mistakes in present practice. All things must have their experimental stages, owing partly to the fact that acquiring knowledge is progressive, and because the men best fitted by nature for pioneering stick closely to an idea which to them looks good. Perhaps one reason why some men have made much money is that they were not inventors and were, therefore, mentally free to chose among all plans. I do not mention many abortive efforts proposed or tried, to forge car wheels, except to say that the most costly one in view of the expense and what it accomplished, was the attempt to use a steel casting wheel and roll the tread. I have been informed recently of a plan to cast wheels of steel ready for use. I doubt the value of this, both as to cost and quality. Three different works use as many different methods for forging wrot steel wheels, while there is another just being put into practice, and a still different method is proposed.

Considering first the cost of material for wheels. One works have been cutting a round blank from a square slab. Taking, for instance, a circle of 28 in. diameter, it will require a piece at least 28½ in. square and this weighs fully 30 per cent more than the circle. Then, assuming that the blank is to weigh 750 lb., there is 225 lb. to be added, making 975 lb., which at $28.00 per gross ton amounts to $12.20. Deduct say 215 lb. recoverable scrap at 75 cents, or $1.60, leaving $10.60. But using the ingot shown in Fig. 9, weighing say 775 lb. at $22.40 per gross ton, makes $7.75, showing a differ-

ence of $2.75 per wheel, using prices of three months ago, not taking into account that the recoverable scrap from the last named would be more than from the first one. This heavy extra charge cannot be continued. Removing this burden will do a great deal to promote the sale of steel wheels. The wheel business needs an Andrew Carnegie behind it.

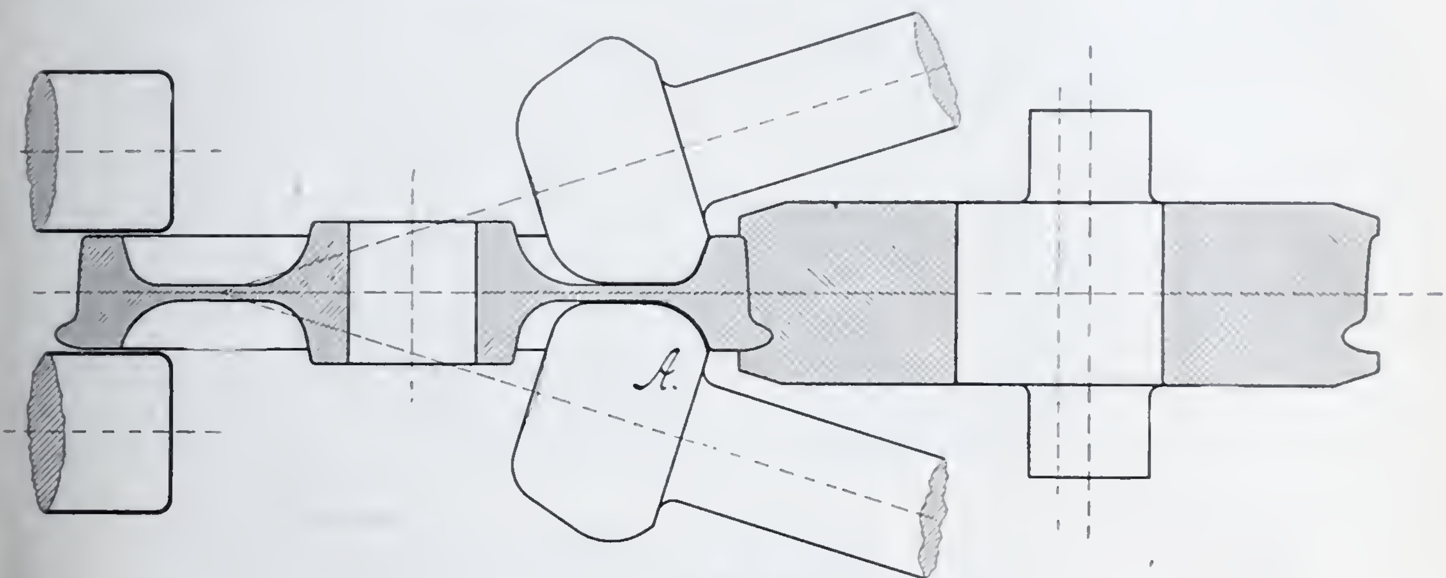


Fig. 4

This 28 in. circular blank about 4¾ in. thick, in one works, is placed between dies in a powerful press which thins the web portion and raises the hub part. The metal in the hub is thus forced to travel in a direction contrary to that of the dies, and this takes a large and needless amount of power. After further press work the blank is finished in a rolling mill outlined in Fig. 4. This method results in placing the outside part of the ingot in two portions of the tread, and the central portion of the ingot in other two portions of the tread, these portions blending into each other. This works use a 7000 ton press for the heaviest part of the forging. Another works use a circular blank about 36 by 2½ in. This blank is pressed into something like the shape shown in Fig. 5 (which is not to scale), the flanges formed around the rim and in the central part being forced down to make the tread and hub. This works I am informed use a 10 000 ton press. They do not roll the wheels, but depend upon the dies for finish. This plan should make the hub and rim concentric, and should make a nice hub which perhaps would not need rough boring. But it

places the central part of the ingot in a rather peculiar position. In the blank shown in Fig. 5, the center of the ingot would likely run something like the dotted line *A* and in the completed rim, probably something like the dotted line *B*, thus bringing the central portion of the ingot close to the face of the tread at this point. Trouble may be expected from "cold shuts," or the tendency for them to form at *C* as the web *D* is being thrown to the center of the rim.

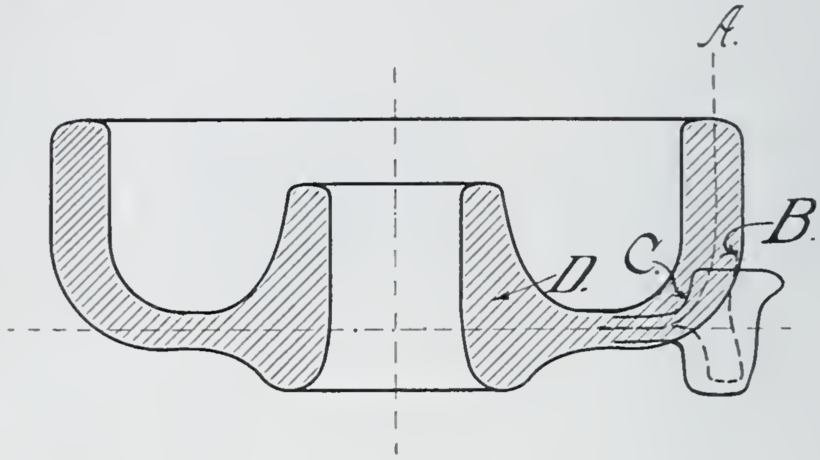


Fig. 5

Another works have been making the blanks from standard ingots with a hammer, forging them in a press and rolling them in the same kind of a mill as the works first mentioned. I might mention as something of a novelty, without any reflection being meant, a plan now being developed for making wheels wholly by rolling, after the blanks have been cut from the ingot and punched. Please note that making the hole in the hub and dishing the wheel are common to all methods.

One works, during my last visit, were cutting the pieces from the ingot under a steam hammer. Another works have been trying a newly designed hydraulic machine with poor success. A different machine has been designed by their new engineer which I believe will answer. This is to do it by power in the way that a good blacksmith would do it by hand on a small piece.

There has been trouble with ragged edged flanges, also in trying to avoid eccentricity in the location of the hub, and in securing a true circle in the tread without lathe work. This is owing to a lack of forging knowledge. Please allow me to sharply criticise any methods of forging so plain a shape as a

car wheel which leaves the truing to be done by machining. From my long experience in forging I can see no reason why a forged wheel cannot be forged as true to the circle as an iron one is cast.

As to rolling, the rim of a wheel is a continuous bar, and the utmost possible amount of work should be given it in the same way a bar or a wheel tire would receive it. The type of mill shown in Fig. 4 really does more effective work on the web than on the tread, as the rolls exert a grinding motion at *A*, on the inner side of the rim. The type shown in Fig. 6 is a better mill. It would leave a rougher surface on the web, but would do much better service on the tread, and like the show, the tread's the thing. Therefore, the blanks should be very heavy in the rim. In Fig. 6 the rolls are shown too large and the blank rim too small to represent my idea.

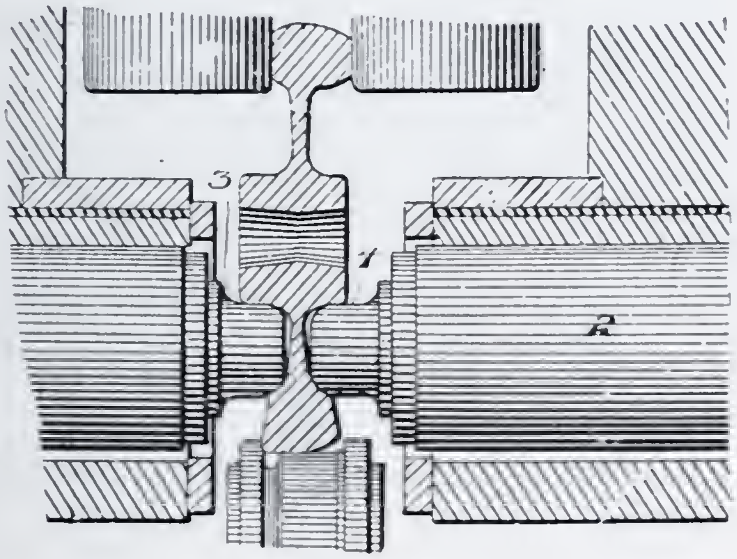


Fig. 6

I was taught that steel articles should be finished at low temperatures, but in articles which are to be heated afterward this is not important. I have made carloads of good track chisels without paying any attention to the temperature at which the last forging was done. Of course I am not speaking of cold work, such as used to produce spring wire, etc. So far as I know none of the wheel treads now made are forged enough in the same direction. After sufficient work has been given to close the blow holes, kneading steel damages, while continued elongation helps it, owing to longitudinal

seams often existing. In other words, working it crosswise and endwise is, as far as possible, to be avoided. This is the reason why the best car axles cannot be made by upsetting methods. Work for work's sake on steel is often worse than a waste of effort. We are told that seams do not exist in good steel, but in piercing a lot of selected 4 in. billets endwise with a pointed punch, thus making 5 in. rounds of them, I found longitudinal seams on nearly every side.

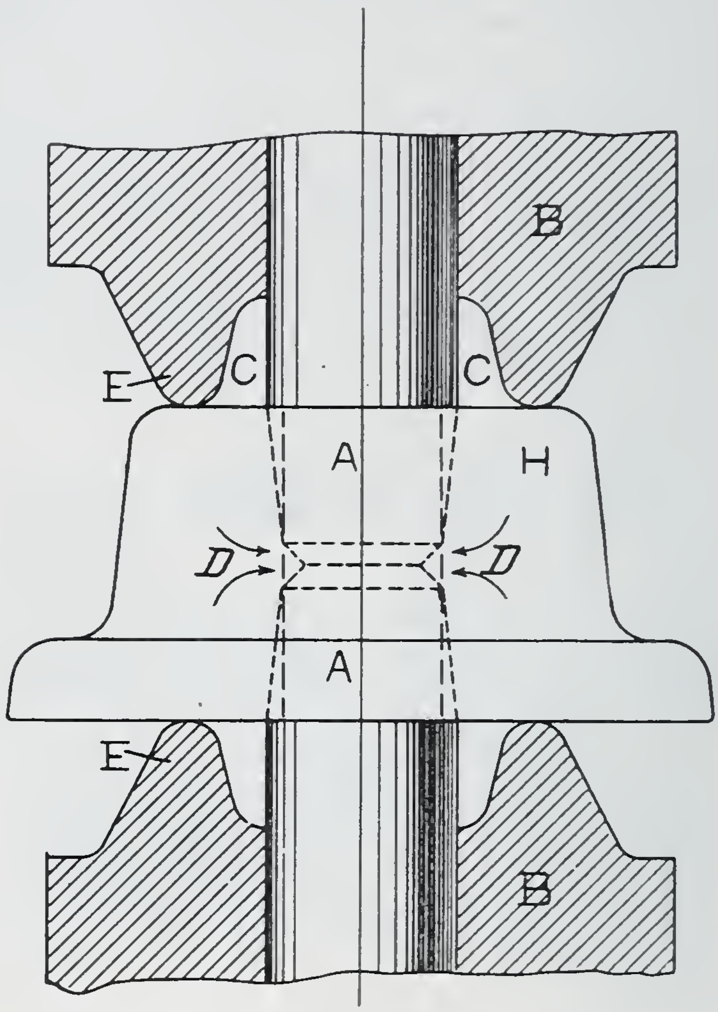


Fig. 7

Next I mention a method proposed which consists in taking an ingot *H* shown in Fig. 7, having a hole through its center. The dies *AA* are brought together in the center and then the dies *BB* are brought toward each other. These will, owing to their shape, proceed easily until the metal which will be imprisoned in the corners *CC* impedes them. Then the central dies are withdrawn somewhat and the imprisoned metal allowed to flow inwardly into the hub cavity. Next, the same kind of an operation follows as shown in Fig. 8 and the third set of dies follows in the same way. The blank is much higher

at the start than the hub is to be, so no metal travels against the motion of the dies, but flows easily from between them, and the hub walls are lowered at each operation, thus giving a good finish. The direction the metal has been shown to travel is illustrated by the arrows in Fig. 9. The tread is therefore taken from the best portion of the ingot coming from between the dotted lines *FF*.

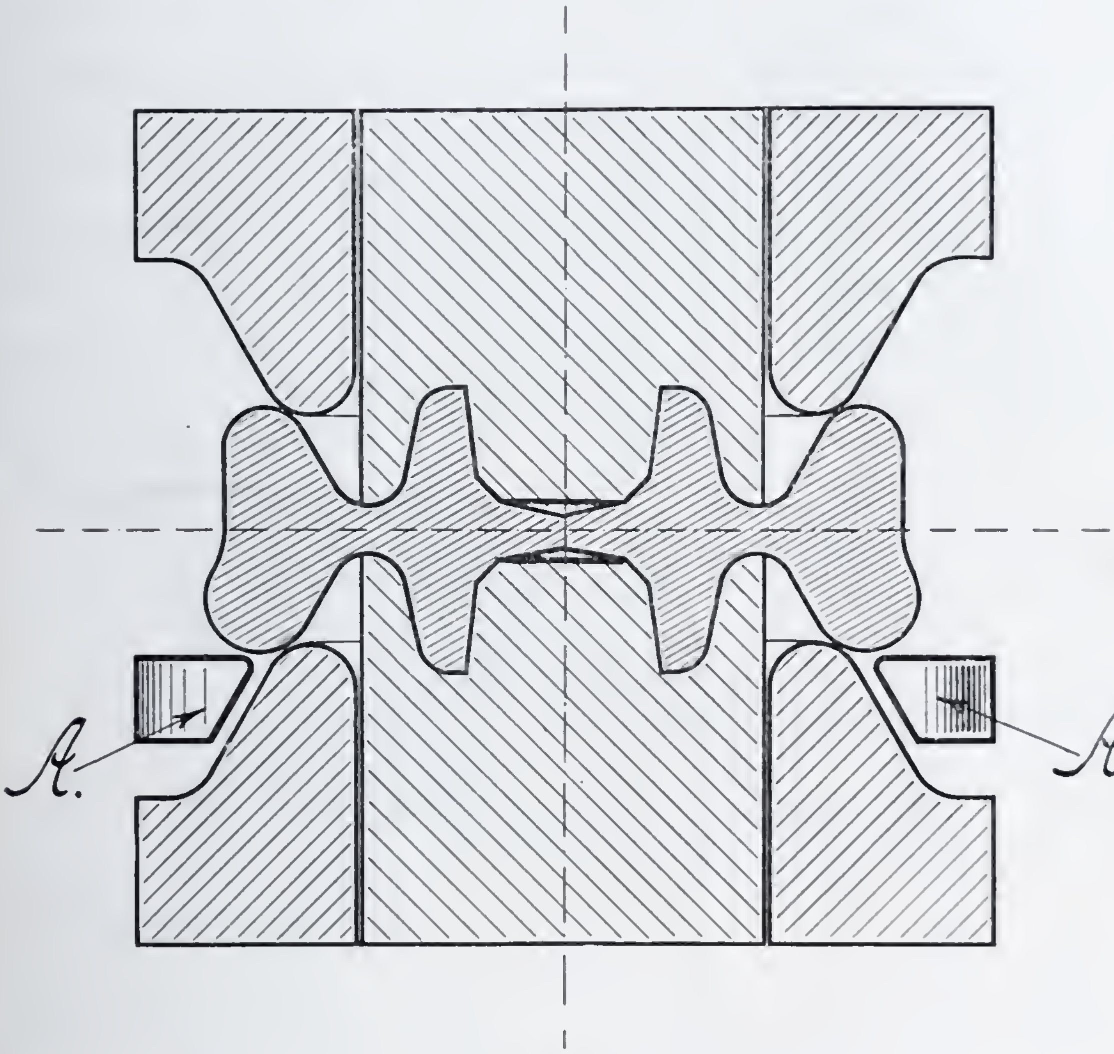


Fig. 8

Correct weight is of importance. Even when starting with the proper amount of material quite a difference may be caused by scaling. In addition to scaling the weight is apt to vary either in cutting the blank hot from an ingot, or in using individual ingots. By this method of forging the ingot can be weighed on its way to the dies and by the simple operation of the first set of dies, and incidentally some variation of power, more or less metal can be let into the hub cavity. This cavity half filled would hold about 30 lb. of steel. The tread portion comes from the best portion of the ingot as shown in

Fig. 9. For very fine work the ingot might be surfaced at its waist before forging. This general form of blank can be taken from a standard octagon ingot by forging. But if this is to be done this work should not be done by a press, but by a hammer of reasonable size, so that the work may mostly be given to the surface which is to form the tread.

In changing these dies the blank is automatically left on the bars *AA*, shown in Fig. 8, as the lower die descends, and the dies are changed automatically. This small sample before you was made by this method in which the inside dies were operated by springs, a poor way compared with controlling cylinders. But it shows to what extent a simple method of forging can be carried, though the blanks should be left much heavier in the rim before rolling. It is demonstrable that this method will not require over one-half the power used in present methods. And there is a vast difference between the cost and maintenance of a 3500 ton press and a 7000 ton machine, to say nothing of a 10 000 ton press.

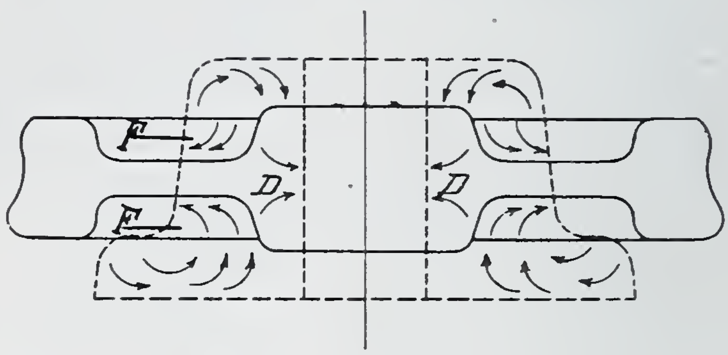


Fig. 9

The characteristic feature of this method is that it forges the blank for a wheel to a point ready for rolling to a finish, by a series of successively acting dies of which each pair makes one impression, withdraws, and is followed by a pair next larger in diameter, and so on, until all of them have been applied.

The principle involved in this process is that the metal is being gradually forced from the center, or hub, toward the periphery, by the successive action of this series of dies; beginning with the smallest diameter, near the hub, and ending with the largest, at the rim, but with the additional feature that whenever one pair of dies has performed its work the

portion thus shaped is firmly held in that state by a pair of "holding down dies" automatically put in the place of the preceding ones, thus preventing any of the metal displaced by the succeeding dies to flow back into the part already reduced to the right thickness.

Comparing this feature with that characterizing the corresponding action in the operation of some other methods in which the entire mass of metal is displaced in the effort of producing the web, the metal being squeezed down in one operation from the thickness of the bloom to that of the web, in which case not only the whole of that work must be done by a single effort, but the resistance resulting from the clamping effect of the large die faces in action also must be met, which greatly increases the requirement of energy over what is needed to attain the same results by the process using successive dies.

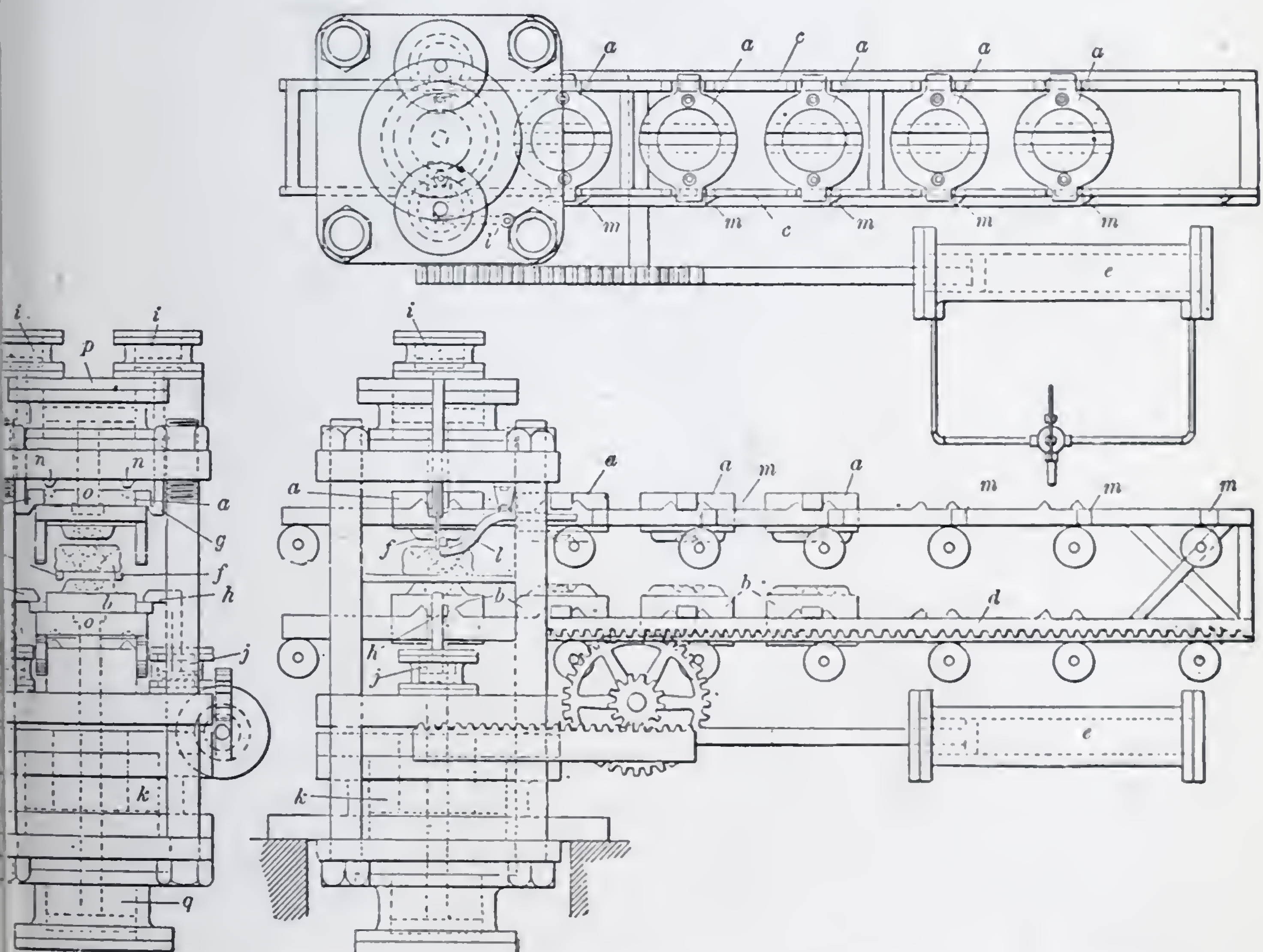


Fig. 10

Were it only for the additional power required in the case of the single stroke forging, it would not signify much, because this would manifest itself chiefly in a somewhat larger fuel bill, but there is to be considered also the large bulk of the machine, its unwieldy details, the more frequent and longer interruptions of the operation due to repairs.

Fig. 10 and 11 illustrate the method of forging in which a succession of dies are used. The dies are held in a pair of movable racks which are shifted after every impression or stroke.

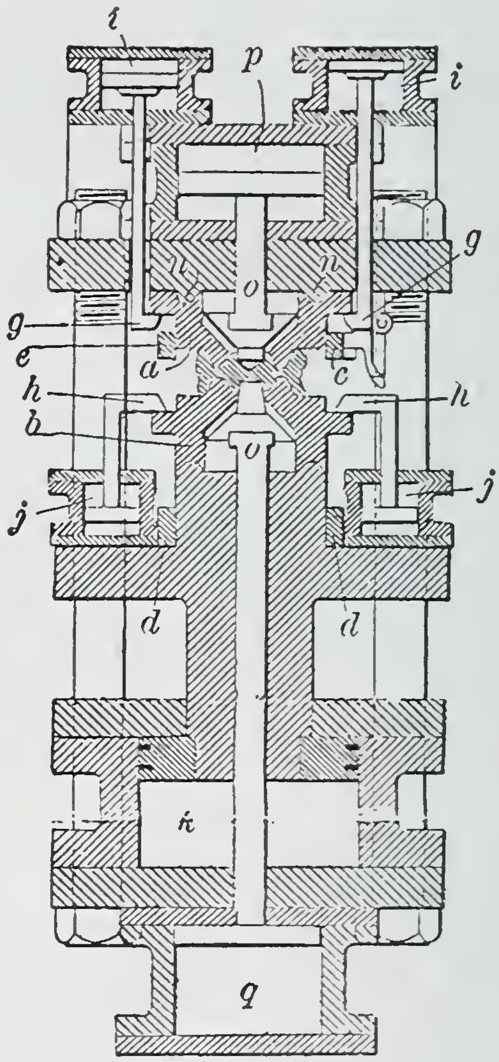


Fig. 11

The blank is automatically taken from one pair of dies, supported while the dies are being changed, and then deposited on the next die. The dies *a* and *b*, Fig. 10, are supported on the connected racks *c* and *d*, which are moved by the cylinder *e* through the rack and gears as shown. In the end view of the racks and elevation of press in Fig. 10, a blank is shown at the rest on two bars *ff*, having been deposited there as the bottom

die descended. The dies *a* and *b*, Fig. 11, are held in place in the press by hooks *gg* and *hh*, these hooks being operated by cylinders *ii* and *jj*. The lower platen of the press, operated by cylinder *k*, having descended and the blank being left on the bars *ff*, the lower outer die is deposited again on the rack, the cylinders *j* releasing the hooks *h*. The upper outer die is similarly released by the cylinders *i*, and hooks *g*, allowing it to be again placed on the rack. The pressure in cylinder *c*, Fig. 10, while moving the dies into place is continuous, and at the end of the releasing movement of the hooks *g* and *h* the lock-

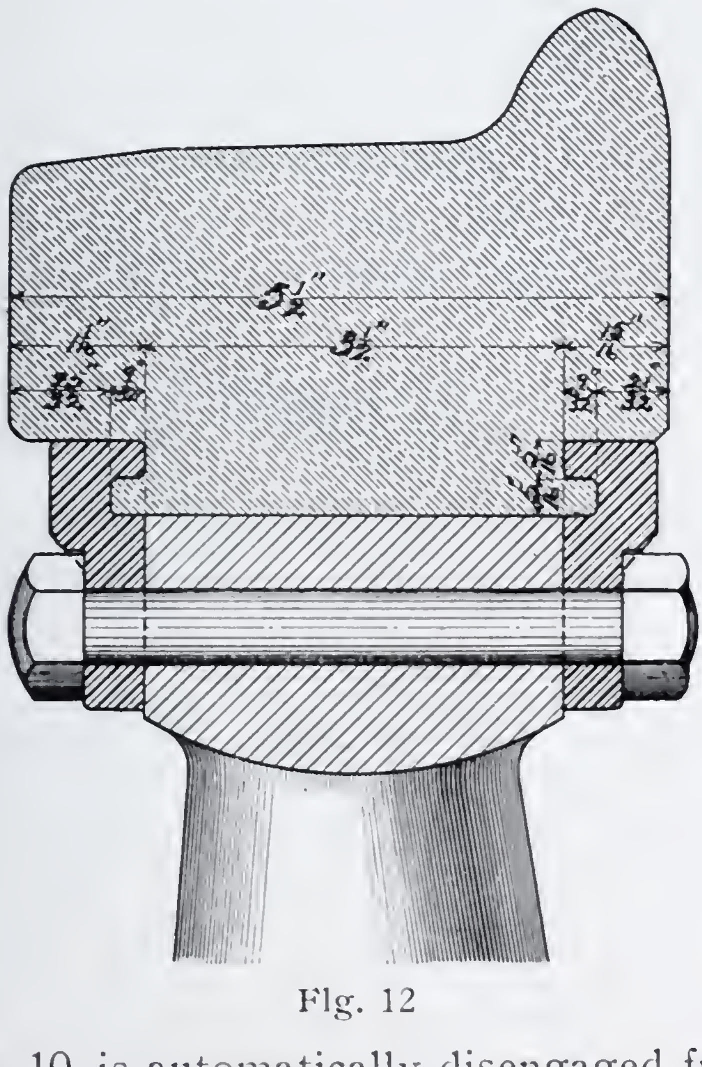


Fig. 12

ing arm *l*, Fig. 10, is automatically disengaged from the lug *m*, and the rack moved forward carrying one set of dies out and bringing the succeeding set into position, the rack being stopped at the right point by the next lug *m*. The upper dies are then lifted into place by the hooks and the lower dies caught by the ascending press platen and both are registered by the beveled projections *nn*, Fig. 11. The inner dies are carried by the outer dies and engage the T heads as they come

into the press and are operated by cylinders *p* and *q*. By an arrangement of springs and latches the bars supporting the blank are automatically spread apart as the diameter of the blank increases.

One of the advantages of this method is that the blank is in contact with the dies the shortest possible length of time, thus holding its heat better and allowing it to equalize to a considerable degree between the operation of the dies. The entire operation would be performed by one man at the levers, thus bringing wheel forging into line with modern methods.

There are those who think that a forged wheel cannot be made to equal a steel tired wheel. Fig. 12 shows how expensive such structures are, and I believe it entirely possible that a rim forged integral with the web can be made as good, and at less than half the cost.

I feel confident that a good forged wheel, at a low cost, is certain to come.

DISCUSSION

Mr. Joseph Morgan: I did not come here with the expectation of saying anything upon this subject, but Mr. Baker did not touch on one branch of it which is of vital importance. In studying this a year or so ago, I found that the Pennsylvania Railroad had about 200 000 freight cars, and of course about 1 600 000 freight wheels running. It is a very vital matter with them to have the wheels safe. It is not alone the safety of the freight train, that may be an unimportant matter, but on four track roads it is more essential to have the freight trains run safely for the sake of the passenger and other trains that may happen along about the same time. Within the last year I have been twice held up on the main line of a four track road by freight wrecks which spread over all four tracks. If a fast express had happened along just at the time the wreck occurred, there would have been a great disaster. Railroad people who are responsible for rolling stock are very much concerned about the present cast iron freight car wheel. They have had much discussion about it, and they

say it has been much improved lately. It is impossible, however, to use cast iron under present loads of 100 000 freight cars with the safety that engineers expect to have in the structures upon which life and property depend.

Illustrating the dependability of forged steel, within a few days there was a freight wreck at Alegrippus on the main line of the Pennsylvania Railroad, where a train broke in two and ran down hill into another train, and wrecked about 38 steel cars. Some had steel wheels, and I am told that out of the entire lot of wheels examined, but one of the steel wheels was cracked, a slight crack showing on the flange, while numbers of the cast iron wheels were badly broken. Of course the steel wheels may have been bent, but they did not break.

When it comes to choosing between cast iron at 16 000 or 18 000 lb. ultimate, and steel at 150 000 lb., few engineers have much difficulty in making the choice. It is a matter of money. To replace a $7 wheel with a $15 or $20 wheel will cost a great deal of money to any railroad, but it is a necessary change, and will be made by the wide awake engineers of our railroads just as soon as they can bring it about. They will do with cast iron wheels as they are doing with their wooden passenger cars, replace them with steel ones. I do not believe any of the railroad men want a steel tired wheel for freight even if it could be had at the same price as a solid wheel. They are too complicated. Just how the wheels are going to be made of forged steel is a matter for the metallurgical men and mechanics like Mr. Baker to work out. There are three or four works at this time making solid steel wheels, and I have no doubt they will get along the same as we have in other branches of the steel business, they will perfect their methods as they grow in experience.

Mr. G. L. Norris: For a number of years past I was connected with a company manufacturing both steel tires and rolled steel wheels, but at present I am only interested in the possibilities of alloy steels for tires and wheels. I think these are the steels that will give the greatest service. The rail of to-day is very much harder than the rail of a few years ago,

and this no doubt has an effect on the rate of wear of the wheel. We cannot very well make the steel in the tires or the wheels much higher in carbon with safety, so the only resource seems to be to use the alloy steels, and I believe the most suitable one for the purpose is a chrome vanadium steel. This is being tried at present by several railroads and the results I understand are very good. My own observation is confirmatory of this.

Mr. Baker's method of making the wheel is very interesting, but I would like to know whether he expects to cast this blank as a short ingot or cut it from a long ingot. I think if he casts it as a short ingot he will get into a good many of the troubles that he has criticized in some of the other methods, notably piping and deep seated gas cavities.

Mr. Julian Kennedy: I have had no experience in making wheels of this kind. There is a good deal of truth in Mr. Baker's statement that the tread of the wheel should be worked as nearly as possible in the same manner as the steel bar is worked in one direction.

I am not railroad man, but I am told that in a certain class of service there is not so much necessity for great durability as for absolute safety. The average freight car probably does not go more than 20 or 25 miles a day, and it has to serve as a warehouse earning its money by demurrage charges as I understand. So for some classes of cars if we get a simple, durable wheel that is entirely safe, it is all right. But it is important that the flanges should be strong and not crack off and wreck a train passing on another track.

In regard to the short or individual ingot I have always felt that it is condemned more than it deserves. There is apt to be a little piping in an ingot and if it is cast hollow as shown, it becomes an annular pipe running between the axis and the outside, but I imagine that would not make such a very bad wheel after all. It would probably make a better wheel if the ingot were cast solid and the center punched out. At the same time for high grade wheels, little difficulty can be caused by casting a long ingot and cutting off and discarding the orthodox 30 per cent.

THE AUTHOR: In relation to the short ingot, that was placed there for the purpose of illustration, as I said in the paper, that same form of ingot could be taken from a standard ingot. That is for the steel men to decide. I would defer to Mr. Morgan or Mr. Kennedy or any of our steel makers when it comes to that. I wrote an article* several years ago describing a method for taking an ingot, to be forged by that method, from a long ingot. I think you will all agree that when an individual ingot is used to make a steel tire nearly the whole of that ingot goes out into the tread. When an ingot of the kind shown in Fig. 7 is used to make a steel wheel the top and the bottom of that ingot go back into the inner part of the wheel, and, as the marks on the sample of our experiments show, the tread comes out of the waist.

MR. SAMUEL DIESCHER: That car wheels can be made by a combination of the forging and rolling processes is a well established fact. Thousands of such wheels have been made by the Schoen Steel Wheel Company. The points to be considered are, which is the best of several processes now followed, and also whether such a wheel should be made from an ingot cast upright, or from a slab rolled from an ingot, containing whatever flaws may have been in that ingot. As a rule slabs are not of a uniform density because they are not homogenous. The different qualities in one and the same slab at various places are certain to have their effect upon the resistance to wear in the tread and flange of a car wheel. They will be most conspicuous in the direction of two diameters drawn at right angles to each other, the one in the direction in which the slab was rolled and the other transverse to it. In the ingot Mr. Baker uses for making wheels the tread is made from the portion of the ingot that is situated between the top and bottom, hence usually free from flaws. The central portion of this ingot is cast with a hole through it. For these reasons it appears to me that the process of Mr. Baker is far superior to any that I know of.

MR. A. STUCKI: Our aim is to get the best wheel possible, even if it costs considerably more and as Mr. Morgan has

* Iron Age, September 7, 1905.

pointed out, we are willing to spend from $15 to $17 instead of $7 or $8 per wheel, expecting to get a wheel that will at least prove to be as economical in the long run. But are we doing all we can to preserve the wheels? Mr. Norris spoke about increasing the hardness of the rails to stand up under the action of the wheels. This again would be more severe on the tread and flange and would actually be robbing Peter to pay Paul.

There is an old saying to the effect, that there is more in saving than in making, and this applies directly to the wheel question. We are not giving this side of the question the attention it deserves. The conditions under which wheels ordinarily are compelled to run, are very severe and strange to say unnecessarily so, and the sooner we quit using them as grindstones against the rails, the better. This will go a long way toward preserving them.

The Pittsburgh & Lake Erie Railroad Company, and a few other roads during the last eight or ten years have done a great deal of good in this direction, and the first road mentioned went so far as to equip about 8000 of their cars with frictionless side and center bearings, so as to allow the trucks to swivel freely in passing curves. The other cars, about 7000 in number, had the ordinary side bearings. After a careful record of the wheel performance for three years it was found that on these two lots of cars the percentage of the wheels removed on account of worn flanges was 2 per cent in one and 39 per cent in the other case, for the same cars, the same road and the same service. On one lot of cars in passing a curve, the side bearings rub hard on each other and prevent the trucks from swiveling, pressing the outer front wheel against the rail and keeping it grinding against the rail until the curve is passed, while on the other lot the trucks can swing freely and the wheel flanges simply act as safety guides to keep the wheels from running off.

Fortunately the expense for anti-friction side bearings are a mere trifle in comparison with the expense connected with a forged or rolled wheel, and a good many roads are now taking this question up very vigorously and in building new cars wil not tolerate the old conditions.

Credit is also due to the Master Car Builders' Association which at their last yearly convention declared in favor of a proper frictionless side bearing, so as to get a more efficient wheel, less flange wear, longer life and increased safety, because a flange is not so liable to break when of full dimensions, as when it has been worn in thickness, and I again repeat that we should pay more attention to its preservation.

Mr. G. L. Norris: I do not wish to be understood as advocating hard rails. It is simply the condition that has come about in the last few years. It means that the tire and wheel maker are strictly up against it, because the rail is as hard or harder than the tires and wheels today, and that is a condition which they have got to meet in some way to obtain the mileage demanded by the railroads. Mr. Stucki's point is well made. I know a road where 89 per cent of the wheels removed are for cut flanges.

Mr. H. H. Anderson: I would ask Mr. Baker if any standard wheels have been made by the process described of successive forging dies, also the carbon in the steel used in the sample wheel on the table, as this is a a factor in forging successfully.

The Author: There have been no full sized wheels made.

Mr. H. H. Anderson: Such being the case it is difficult to determine what the results will be, when the process and wheel is shown on paper only. Actual service conditions are the best and only tests to give definite results as to the qualities of a wheel. It is a common saying that a person's "hind sight is better than his foresight," and I feel that results will demonstrate that it will apply in this case. In criticizing the wheel manufactured as shown in Fig. 4, while we have encountered difficulties, as would naturally be expected in such a radical departure from beaten paths and in developing a new industry, still the points brought out by Mr. Baker as being the weak points in the manufacture of a wheel from a slab do not deserve the prominence given in the paper. They are not

borne out by actual service, and while we may theorize as we please, the proofs arrived at by regular use under working conditions are what govern. From tests made of the steel in various wheels and tires purchased in the open market, we found that the Schoen wheel was harder and showed greater resistance to abrasion than any of the others.

The mileage which is the important factor with the railroads, shows a total without turning, of 184 539 miles for 0.348 of an inch wear with a wheel load of practically 13 000 lb. On tender truck service, which you will all agree, is the hardest service to which wheels are subjected on steam railroads, we show 25 405 miles per $\frac{1}{16}$ in. wear. On street cars where we have the grinding due to the grit and sand on the rail and brake action due to the numerous stops, we show 10 000 miles per $\frac{1}{16}$ in. wear. From the figures given, all obtained in actual practice, I feel that our claim that the wheel has given exceptionally good satisfaction is substantially confirmed.

The figures as to the weight of steel required, and the amount of scrap taken from the slab are higher than found in actual practice.

In regard to the piping in the ingots from which these slabs are produced. This is taken care of by a liberal discard from the section of the ingot where the piping or segregation is liable to occur, as it does to a greater or less extent in all ingots.

Mr. S. S. Wales, who is with us tonight, can give more information as to the structure of these wheels from actual tests he has made.

Mr. S. S. Wales: I am not a wheel user, but have simply a general interest in steel from a metallurgical and physical standpoint.

Some time ago I took up an examination of the Schoen wheel that was not exactly cursory and yet not exactly exhaustive, but we discovered some things which might be of interest to you covering the point which has been brought up, that in a wheel made from a slab are found four distinct points,

two on opposite sides where is found the good portion of the ingot and two on opposite sides and at right angles to these where is found the piped or segregated portion of the ingot. To determine the extent to which these points of difference existed, three distinct groups of wheels were taken, one of standard Schoen wheels made from slabs, and one of experimental Schoen wheels, made from a long ingot sliced, and one of experimental Schoen wheels made from sections cut transversely from a bloom and upset in a large press to form what is vulgarly known as a "cheese" or biscuit, these being 20 in. in diameter and 10 in. thick.

At the beginning it was thought desirable to know the direction of rolling of the metal in the "slab" wheel, and, therefore, the hub was cut down to several depths and etched with acid each time, but the direction of the fibre could not be determined definitely.

All of the wheels comprising the above groups were cut into 12 segments and from each segment six pulling tests were cut, ½ in. diameter by 2 in. between punch marks. Two tests were taken from flange region longitudinally, two from the tread longitudinally and two from the tread transversely to circumference of wheel. From all of these were obtained tensile, elastic, elongation and reduction tests, and around the wheels made from the slab there was a maximum of, I should say, 6 per cent variation in the tensile and other properties. As far as tensiles and elastics went we could find hardly any indications of the fact that one set of wheels was made from slabs and the other made from a "cheese," the original structure having been almost entirely obscured. Further, by giving these wheels a heat treatment, the slight indication if any existed, disappeared. This would indicate that the work done on the tread practically eliminates any difference one would get in the original slab.

The point I want to make is that in taking these longitudinal tests continuously around the tread, as described above, we are bound to cross the zone somewhere where the middle portion of that ingot was, and we are bound to cross these

better portions, and that in these investigations no such points were indicated by the results obtained.

We have made some experiments in treating wheels and it is entirely possible to make a wheel that would wear out any rails now in service, but I would not recommend using as hard a wheel as that.

Mr. Julian Kennedy: If you were going to make wheels which would you prefer, slabs or slices across the ingot?

Mr. S. S. Wales: I do not know that I would care to go on record as to which I would prefer to use, as I was simply making the point that the wheel was not noticeably ununiform when made from the slab as has been supposed, but I do not consider that we would care to make a wheel out of cast blanks with the other methods available. It would be preferable to put some work on the piece before beginning to make it into a wheel. It might be only a light working of the ingot with a hammer, as was suggested, or a small amount of reduction in a rolling mill.

Mr. F. D. Ward: My forte has always been listening rather than talking. I was with the Underground System of London, promoted by Mr. Yerkes, for 3½ years, during which time we had constructed about 1000 cars, all of which were equipped with built-up, steel-tired wheels. The roads were practically all underground, in tubes sheltered from wind and rain, which, in the open, tend to clear the rail of small particles of steel worn from the tires and rails in service. These particles act as an abrasive between the two surfaces and cause excessive wear to both the wheel and rail. The tonnage was low compared with the 100 000 lb. capacity cars here, but still the rails wore and wheels cut away at the flanges badly. We got some relief by changing brake shoes, having been using a practically grey iron shoe, and giving special attention to the track. Steel-tired wheels were used exclusively and I am of the opinion that when steel wheels come into universal use and the hard surfaced cast iron wheels are discarded, the wear of rail and wheels will be greatly increased; as the chilled

wheels now in service tend to keep the rail in a smooth planished condition. The action, as a gentleman mentioned a few minutes ago, is like a grindstone. The small particles of steel acting like sand between the two surfaces, and is much worse where the track is sheltered and the rails cannot be cleaned off by rain or air currents. English roads use steel-tired wheels universally, and are operated at high speeds, which, as a whole, are higher than in the United States, though their runs are short, over good road beds with practically perfect alignment, and no rail or wheel wear other than what might be termed legitimate. Their rolling stock is lighter than that in service here and traffic on a given track is always in one direction, both of which no doubt have an influence. When abroad we look back to the United States for new ideas and devices, but some of the old ideas in the old country are hard to beat. An English eleven and a half ton car, 36 ft. long, seats 50 passengers comfortably—a little better, I think, than we do here at home. I experimented with hard and soft tires in elevated service in Chicago, the tests extending over a period of two years, and found soft tires showed less wear than hard ones. I also tested the same type of tires in England with the same results. I would be pleased to have some of the steel men present explain this to me, as I cannot understand it, but am thoroughly convinced that the soft tire gives the best wear.

THE AUTHOR: I was in a tire mill where they were cutting the ingots into cheeses or blocks cold. They ran in a one-inch parting tool to within about two inches of the center of the ingot and then broke it off, thus being able to see what kind of a fracture they had, and I saw one ingot that had a hole as large as my fist near the bottom. Had that been rolled that seam or condition would have been there. Mr. Ward's remarks about soft and hard tires were very interesting and I shall look into that feature of the question. As to the point, mentiond by Mr. Anderson, that we have got to fall back on practice and not take any theory whatever, if that is true, gentlemen, about 75 per cent of the membership of this Society might just as well quit being engineers.

Mr. Harry J. Lewis: While I know very little about the making of car wheels there is one question which has not been raised in this discussion definitely. The most important point in the car wheel is its contact with the rail. With a journal bearing of say 5½ by 10 in. or about 55 square inches, the rail head is about 2½ in. wide. I have been asking some of my railroad friends about the area of bearing between wheel and rail and they agree fairly well that it is not over one square inch. The gross weight of a loaded 50-ton car is about 150 000 lb., which divided among eight wheels is 18 750 lb. per wheel. If the square inch of contact area is correct, we have 18 750 lb. per sq. in. on a bearing which is not uniform, but most intense under the center of wheel and diminishes to zero at the forward and rear edges of contact. This load is suddenly applied and removed and often repeated.

The question is whether we would design any other engineering structure and use the same unit strains as probably occur between wheel and rail. It is my impression that the elastic limit is often exceeded in this contact as the outer edge of the rail head often shows a slight fin which has flowed out from under the tread.

The problem now before the rail maker appears to be the making of a rail hard enough not to flow in the head, and sufficiently stiff and tough to carry often repeated and suddenly reversed loading. This appears likely to result in a rail head of increasing hardness, and if we oppose this hard rail with a hard wheel tread the two are likely to grind each other to pieces. May it not be true that a part at least of the solution lies in a soft, tough wheel tread which can endure sufficient deformation to allow the distribution of the bearing over a reasonable area?

Mr. Julian Kennedy: The soft rail will distort just the same as the hard one under a given load. As long as it is within the elastic limit I do not think 100 000 lb. on a soft rail will affect it any further than the hard one. After we get beyond the elastic limit we simply roll the head off the rail.

I think a great deal of this question of wear is a question of material. A hard steel slide on an engine cuts a hard steel

bar and goes to pieces. At the same time on a rail of different temper the train will not grind as much when it comes to flange friction. I believe a great deal can be done by having the trucks swivel well, and I believe they would run better if there was more taper on the wheel and more clearance between the flange and the rail. I believe with a little more coning and more leeway between the flange and the rail, wheels would run over most of our roads without the flange ever touching the rail, if they swiveled sufficiently. I believe if the ties were spotted so the rails could be converged and the wheels made with more coning and at least 1/4 in. more clearance, we would have much longer life in the wheel. Another thing is to take the brakes off the wheel. In some places they are now discussing using a separate rim for the brake.

Mr Joseph Morgan: As to increasing the cone, I think that has been done by the railroads within a few years. When they got into trouble with the heavy cars and cast iron wheels they did increase the coning which helped the wheel somewhat, but the trouble is the wheel load seems to be too great to carry 100 000 lb. cars upon cast iron wheels.

Mr. H. H. Anderson: In regard to Mr. Lewis' point about the railroad wheel. Mr. George L. Fowler made some exhaustive experiments on that point and there is only 0.25 sq. in. of contact with 20 000 lb. pressure. Also with loaded cars, if they stand on the rail a certain time, a deformation of the rail in perceptible, conforming to the contour of the wheel. In regard to the coning of the wheel, some experiments were tried on a certain road of increasing the coning from 1 to 20, to 1 to 13, to take care of the 100 000 capacity cars, but even then when such wheels begin to wear, after a certain length of time the coning is altogether taken away and they get into a groove. We find a good deal of flange wear, especially unequal flange wear on different wheels on the same truck, and that is due very frequently to the axles being out of line. That has been one common source of flange wear. The roller side bearing Mr. Stucki spoke of, has been tried on one of our local roads with considerable success in taking care of flange wear. But

when we see cars go along with unequal load and down on the side bearings on one side, it stands to reason that excessive flange wear will occur on some of the wheels.

THE AUTHOR: I have here this evening a number of reprints of an article * I wrote recently on wheel forging which you may take with you. The article touches briefly on some things and refers specialy to old patents. From the very beginning of railroads, forged wheels were talked of and many of the features under consideration today were discussed and patented seventy years ago. It is a little historical sketch mentioning methods for hardening the tires, mills for rolling, etc. For instance you will find a rolling mill something like that shown in Fig. 4, the first patent on which was taken out by Mr. Singer about sixty-five years ago in Pittsburgh, for rolling circular plates. You may find in this little article some things of a moment's interest.

* Industrial World, June 8, 1909.

SOME OBSERVATIONS ON STRUCTURAL SHOP MANAGEMENT

By Samuel E. Duff.

Mr. President and gentlemen of the Structural Section of the Engineers' Society. I shall not be able this evening to give you any general formulae or exact diagrams relating to the subject of structural shop operation. That subject is too complex to permit of such precise treatment. I only hope to tell you of some of the impressions which I have received as the result of coming into contact with the many stubborn facts and unchangeable conditions found in the fabricating business. What I am about to say, therefore, is not to be considered as the demonstration of any preconceived theory, or even a statement of all the elements of a problem, but more as a series of confessions of a number of failures which I have had a part in, and perhaps a boast or two of some things which now seem to have been a success. I do not feel competent to lay down any general laws or anything which might be considered as axioms in the matter.

Some men in charge of industrial plants seem to think that the plants are operated principally for the purpose of giving them a good job, and they bend all their energies to holding that job regardless of how they do it. Other men seem to imagine that the plant is operated to provide them with an experiment station to work out any theories they may have at the expense of somebody else. Still others seem to believe that their position entitles them to work out petty spites, settle personal quarrels and work out revenge on their unhappy victims. I will confess that I have been imbued more or less with some of these ideas at various times, but it finally occurred to me that the real object of operating the shop was to make money.

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The making of money may be accomplished in various ways, but I propose to limit it to two ways in this discussion. First, a shop should be operated to make money honestly; second, to make money honorably. I do not say that money cannot be made dishonestly, I do not say that money cannot be made dishonorably; but I do say that those methods of making money are not worthy of our notice. By the word *honestly* I mean that a man should not obligate himself to any contract he is not morally certain he can complete; and in the second place he should complete in its entirety and to the best of his ability any contract he voluntarily assumes. By *honorably* I mean to indicate that a man should act fairly and openly with the employer who pays him and with the employee who works under him.

If a man is to avoid assuming an obligation or contract that he is not sure he can fulfill he must thoroughly understand what that contract specifies. And this brings us to the first important point in this discussion. I cannot thoroughly explain my views of shop operating without including in them one thing which is ordinarily embraced in the duties of the contracting engineer or general manager and not usually considered as a part of the operation of the plant. This refers particularly to the taking of the contract in the first place. One of the most important things in the structural business, or any other manufacturing business in the contracting line, is a thorough understanding of the limits and details of the contract itself. I believe more money has been lost by an imperfect understanding of the obligations of contracts, than any other point that can be mentioned. You are all familiar with the disastrous losses which occur in the structural business and I think you will bear me out on this point. It may be held that more money is lost in the erection than in the fabrication of the material on account of the greater uncertainty in that part of the work, and that, of course, is true. But what I mean to say is that a great deal of money is lost simply because the limitations of the contract are not thoroughly known when it is taken.

This bears particularly on the point regarding the honesty

of operations. You are all familiar with the deep disgust that pervades the shop from the boss to the rivet heater whenever they have anything to do with a contract which has a large number of changed drawings, changed mill orders and changed templates, holes to be punched after the material has passed through the punching department, holes and rivets to be put in, in the finishing department, corrected shipping bills, etc. If we consider what all this costs it will be seen that one of the most vital points in this business is to understand what is required to be done in the first place. These things may occur through no fault of any person in authority. A change may occur through the uncertainty of the customer himself; when this is the case it should be paid for by the customer. But in my experience the fabricating company by its own carelessness generally puts itself in a position where it is unable to collect from the customer anything at all for his changes. So I call your attention to this fact as one of the most important, bearing on the subject.

I would like to mention at this point a principle I think vital in shop management, and to which it is somewhat difficult to give a name. I am going to call it the *principle of accurateness*. I know of no term that conveys just exactly what I have in mind so I am forced to adapt a word to the meaning I wish to express. The word *accuracy* refers to the character of a single operation or to the result obtained by any number of operations. The word *accurateness* I would define for our use this evening, as the principle which governs the arrangement of a number of different operations so that they will come in that sequence which will produce the desired result without any duplication of these operations or the introduction of any operation not necessarily required.

Let us apply this to the structural business, and particularly to the step to be considered next, where the information is passed from the contracting engineer to the drawing room and the shop. I was acquainted at one time with a fabricating company where it was the custom of the contracting engineer, when he got a good contract, to send for some favorite draftsman, show him the drawings, making hurried sketches

of things not clearly shown, giving verbal instructions on all the points he could remember and tell him to get out the mill order at once as the contract must be pushed. About the same time he would send for the order clerk and tell him of the contract; instructing him to keep after the draftsman until he got the mill order. The draftsman promptly laid aside what he was doing and took up the new job. The chief draftsman finding him working on something new is told that the boss gave him a new job. Sometimes the chief draftsman allows things to take their course and the draftsman goes ahead with the mill order. Reaching a point where the information is not complete, or where two sets of figures are given which do not check, he goes to the contracting engineer who perhaps straightens it out if he has time. After the draftsman has been down to the contracting engineer a dozen times, the latter tires of the interruptions and tells him to figure it out the best way he can. The result is that the mill order is not correct and in consequence the job is full of corrections and changes from beginning to end. From the layer out to the finisher, no one ever had two consecutive days' work on that job. This is an aggravated example of disregarding the principle of *accurateness*. If the contracting engineer had turned the information over to the chief draftsman who would go over it carefully with the draftsman he believed best fitted for handling the work, and, noting all inaccuracies and lack of information, would immediately take steps to correct the information given and secure that which was lacking; meanwhile laying the work aside until the correct information was at hand and until the draftsman had reached a suitable stopping place on the job he was working on; then taking up each step of the operation in its proper sequence and completing it, that job would have gone through the drawing room without the rest of the office knowing it was there and through the shop without creating a disturbance. Some day the contracting engineer would hear that the shipping bill checked up O. K. and he would probably hear later that the work had been turned out within the estimate.

After the information has been properly given to the

drawing room, the next step is the mill order. In making the mill order the draftsman should be careful to calculate the finished length of every piece. Any attempts at short cuts, guesses or approximations are generally unnecessary and a waste of time, and they are contrary to this principle of taking everything in its proper sequence. The greatest trouble I have found in having material orders made is due to a lack of knowledge on the part of the draftsman as to the operations through which the material passes in the shop. This is a very unfortunate circumstance and one that is hard to correct, as a draftsman may go through an engineering school, even the best of them, without ever being inside a fabricating shop and cannot be expected to understand the exact use or the exact limitations of the tools, and he is sure to get into error. I have given this subject much thought, trying to devise means by which draftsmen beginning work in the drawing room could be placed in the shop to learn the operations that the material undergoes. It is a mistake to have a lot of fellows around a shop not doing anything; they are in the way and are liable to be hurt, and the superintendent and foreman do not like to see them there. It is a mistake to expect a college graduate to run a machine. He is not built for it, he is not trained to it, and he should not be expected to do it. I am not in sympathy with the idea of forcing young graduates into dangerous positions around machinery in order to teach them the use and operation of machines. That is not necessary, but it is necessary for them to understand what actually happens to structural shapes in order to put them into the condition required for the finished work. Many of the mistakes charged to the drawing room are due to the draftsman's lack of knowledge on these points. If any one can devise a system whereby the young draftsman may be taught shop practice, it will be a great improvement to the trade.

It would be impossible within the limits of my time to point out many of the ruling points governing the ordering of material except to say that great care should be taken to order all parts of each finished piece at the same time. I have seen much confusion ensue where the idea was to order all

material of one size and shape, and then go back and order all of another shape, etc. That is a very dangerous practice. The order should be made complete for each integral piece, as far as the raw material is concerned. If the order clerk wants to bring all the angles together, or all the universal plates, etc., let that be done outside the drawing room and with no reference whatever to the drawings.

When the mill order is completed in duplicate, one copy should be sent to the shop superintendent, and the other to the rolling mill, which should have in addition certain information about sheared material, that is material ordered in multiple lengths. The purpose of putting a copy in the hands of the shop superintendent is to allow him to provide room and means for handling the material, and this information must necessarily reach him before the detail drawings of the work. A man who is familiar with the business can generally judge from the mill order what the finished work is going to be. In a busy shop where there is an accumulation of probably three months' material, it is quite a problem to receive and handle that material without transgressing this principle of *accurateness*. Sometimes the yard foreman is picked for his ability to unload cars. My experience is that he should be selected for his intelligence, memory and ability to keep things in an orderly manner rather than for ability to unload cars at high speed. This is an important point, bearing especially on the cost of shop fabrication. If the material accumulating for three months before use is allowed to get into confusion, the cost of rearrangement is almost beyond belief. To reduce it to a cost per ton would seem nonsense, but it is true that the material can get into such shape that the cost of untangling the yard will knock the profits off the contract and off of every contract that goes through for months. So it is necessary to furnish the fabrication shop with complete information about the mill order, the time when it is expected from the mill and some idea of when it will be put through the shop. I have known shops where this was entirely disregarded and it was thought that the shop superintendent should not be given information unless he asked for it. I

mention this as the contrast, the absolutely improper thing. The shop superintendent should be given full information and be promptly advised of any change or cancellation in the mill order or anything else affecting the material. He should also be given the original shipping manifest from the mill immediately. In the Pittsburgh district it often happens that the material is received at the plant before the shipping bill. This is due to the fact that the car is shipped as soon as loaded whereas the bill has to go through the clerical department. I want to bring out the point strongly that the shop superintendent who permits a car to be unloaded without the original mill manifest is not only making trouble for himself but nearly always extra cost for the company.

Another vital point is that the material must be carefully checked on its receipt in order to determine at once what material is lacking or imperfect. If this checking is omitted, and the material reaches the punching department, or the layer out, before the shortage is detected, the cost of waiting for required material will outweigh any possible cost of inspection on the outside skids. Many people think this is unnecessary, but it is one of the steps in a long line, as mills will make mistakes, especially in busy times.

Regarding the unloading of material it is impossible to lay down any general rule, because the size and shape of the shop and the tonnage handled determines the type of apparatus which will serve it best. But there are certain general conditions which may be noted. I think an overhead crane, either of the gantry or runway type will give the best results, and the crane should have sufficient power to remove from the car a "lift" of material, as it is called, just as it is placed by the mill. A crane which can only take a small portion of this lift is necessarily more expensive to operate than one taking a complete mill lift off the car and placing it on skids where it can be sorted and checked. To lay down any rules as to the size of the yard, or its arrangement for separation of different materials is manifestly impossible without laying down strict limitations on the plant itself. I have seen several plans tried. One scheme was to keep all beams at one place, all

angles at another, all plates at another, etc. Another plan was to keep all material 20 ft. long in one place, all 30 ft. long in another, etc. I do not remember ever having seen one of those yards stay in that shape over a week. I think the best way to handle a material yard is to have a good material man. The handling of a material yard properly is a personal matter, the man in charge has to give it his entire thought, and if anyone on the outside presumes to tell the yard foreman how to pile his material he should be willing to stand the extra cost and trouble that results. Matters of this kind should be left entirely to the man who has to do the work because he is the only one competent to take into account all the elements of the problem.

With regard to moving the material into the shop, I think the vital point is to make sure that too many people do not interefere. If the material is moved in at the wrong time, if more is moved in than can be readily taken care of, or if it is not at hand when wanted, an extra expense will ensue. The ordering of material from the yard into the shop should be in the hands of one man, preferably the foreman of the laying out or punching department, and any attempt to hurry it up by the superintendent ordering it in without a written order, or any other disregard of this principle of *accurateness* is unnecessary and will result in loss. I do not mean that I am a believer in red tape or in keeping records simply to have a record of every operation, but I do mean to say that in a good sized shop material should not be moved from the yard into the shop except on a written order which should be in duplicate, the man making the order retaining one copy, the other being given to the man whose duty it is to bring the material in. The material should be carefully checked again when it leaves the yard and when it is received in the shop. The purpose is not to duplicate records, but to test the accuracy of the men, as the accuracy of the workmen is a very vital point in business, structural or other lines. If this system does not accomplish anything else it prevents quarreling between those two men in regard to the material. I know this will be strongly criticised. I know shops where it is the custom for

the boss to go out in the yard and tell the yard foreman to throw the stuff into the shop whether it is ordered or not. Get it in there and get everybody stirred up with the idea of getting it out. I have seen that tried many times and much material is taken out into the yard again. All such schemes for cutting across lots and hurrying up are in the end an element of unnecessary cost.

After the material is in the shop it may be taken first to the punching, laying out, or shearing department. It is impossible at this time to follow out all the ways in which it may start, but I might mention them briefly. If the shop is equipped with spacing punches it may be possible that the material can go from the yard directly to the spacing punch without touching the laying out department or coming in contact with any other workmen except the man who runs the spacing punch. It is usually necessary, however, to have the material sheared first in order to square it up on the end, before going through the spacing punch, as it is very seldom that material is sheared square at the mill and if there are two lines of holes in each leg of an angle for instance, and the legs are not sheared square, the ordinary spacing punch is liable to give inaccurate punching on account of the grip of the carriage of the tool not starting at the same point in each leg. Other material may go to the shears for cutting into short lengths in which it is to be laid off and punched. Other material will have to go to the laying out skids.

In regard to templates it is the practice of some shops to make a template for practically every piece of material that is to be punched. I cannot say very much about this method as I never had experience with it. I never could see the necessity of making wooden templates for every piece, and on work I had charge of it was not done. It is necessary to make wooden templates for many things, but I never saw the necessity of wooden templates for web plates or anything of that kind. I do not see why they cannot be laid out on the original iron and that piece used as a template for the others, with just as great accuracy as by making a wooden template and using that template on the steel. Of course the advocates

of the template system claim that there are more checks possible than where the material is laid out directly, which is true. It is also claimed that a higher class of workmen is required to lay holes off directly on the steel than when a wooden template is used and that is also granted. But taken all through, I think the cheapest possible method is to make only those wooden templates which are absolutely necessary; avoiding their use for web plates, girders, columns, or anything of sufficient size to permit handling on the skids without distortion and in which there are no elements that will prevent the laying off from being accurately done. The method which brings about the greatest reduction in the number of templates, however, is the use of automatic spacing punches, which are coming into more general use all over the country. It would be impossible at this time to enter into a discussion of the different styles of automatic spacing punches. But I will say as the result of my experience that any spacing punch depending on the use of brakes, friction bands, counterweights, springs, etc., for the accuracy of its spacing is a dangerous machine. The spacing punch should be absolutely positive and of the simplest possible construction so as to prevent injury by the common workman and not require a machine shop and an expensive machinist to keep it in repair. I have seen some very ambitious machines built at heavy cost, practically useless for the reason that the principle on which the spacing was based was inherently wrong and accurate operation was impossible. I recall a machine in which the spacing was done by means of a rack and pinion movement which depended for its proportion of space on a link mechanism in connection with the main punch head shaft. The punch head revolved with each upward and downward motion of the punch. By introducing a Stephenson link motion between that reciprocating motion and the motion of the rack it was theoretically possible to exactly regulate the forward motion of the rack. But as a matter of fact it was not possible, practically. The inertia of the rack which varied with the load carried, had to be taken care of. If it was loaded with a ¼ in. plate its tendency to move past the proper point

was far different than when loaded with two or three 24 in. beams. It was necessary to introduce a brake in that machine to overcome the tendency of the table to overrun, due to the inertia of the moving parts. In other words there was an element in the machine which had to be left to adjustment of the operator. The rack should be so arranged that it cannot overrun. It must stop where it is supposed to stop and stay there until the punching operation is completed.

Another very important point in connection with spacing machines outside of the fact that they eliminate the cost of templates is that, if they are of correct design and properly handled the work is far more accurate than work laid out in the ordinary manner and center punched. This accuracy reduces the cost of both fitting and riveting. It has an appreciable effect in lowering cost of putting the work through the entire shop. I state this as a fact because I have traced it through several times and know it to be true.

In regard to punching work laid out with a center punch there is a difference of opinion as to whether it is best to use the clutch and foot treadle means of operating the punch or the system of allowing the punch head to run continuously and tripping the punch by means of a hand gag. There are strong claims made for each method and I do not wish to attempt to decide between them, except to say that I have had more satisfaction with the foot treadle type than with the hand gag. In using the foot treadle, the hanging mechanism for the material should be so arranged that the material is kept up against the punch allowing the punch to find the center punch mark much more easily than when the material is allowed to rest on the die block and the operator is allowed to shoot at it as best he can with a hand gag. I believe a workman can punch many more holes, as holes, with the hand gag than in the other manner, but the difference in the number of holes is of less importance than the liability to error in the work from the use of the hand gag.

With regard to the shearing operation, which is the next thing in order, I do not know that a great deal can be said except that this is another point where the matter of *accurate-*

ness or the proper sequence of events is again prominent. The principal thing I can say with regard to a shearsman's shop is to ask you to give him a chance. The shearsman generally has to take orders from half a dozen different men at once, unless things are very carefuly arranged for him. He is supposed to shear all kinds of material in all lengths and to keep his gauges ready for instant use and instant change. There are many small tools which may be used on material that has been punched which enables the shearsman to get the exact distance from the last punch hole to the end of the angle in a very convenient way and much more cheaply than if he used a scale and a piece of chalk and marked the angle first.

The next important step in the shop is the fitting of the material and I suggest giving the fitter a chance. Give him good skids to work on, encourage the use of blocks, clamps and bolts, and discourage the use of haste and drift pins. Careful fitting and accurate bolting up with proper spacing blocks and sufficient bolts and clamps to maintain the true position of the material while it is passing through the reaming and the riveting departments will decrease the cost of these operations, the cost of finishing, and greatly decrease the black marks that the inspector will put on the material when he gets at it.

I want to say another thing at this point. Many people fail to realize the proper and true attitude of the workman in a structural shop, thinking that he is there only to put in his time and to do just as little as he can. The average workman in a shop is probably more vitally interested personally in getting work done with reasonable dispatch and accuracy than the boss and all that is necessary is to give him a chance. Give him drawings which are correct; blue prints which he can read and light enough to read them. Give him plenty of bolts. Buy him a few new bolts once in a while because bolts are cheaper than his time. Encourage the use of special devices for putting the material into exact shape.

The riveter operator should have nothing to do but drive rivets. He should have the material placed on his skid and taken away again, and have proper means for lifting and carrying the material. If the riveter is movable he should have

quick and accurate means of moving it. If it is pneumatic, it should depend for its action on a lever principle rather than a toggle because with the toggle motion which requires adjustment of the set, the matter of getting a tight rivet depends on the watchfulness and skill of the operator to a large degree, whereas if the machine depends for its final pressure directly on the action of air in a cylinder, the operation is positive. See that the operator has proper air pressure at his machine. Ninety pounds on the power house gauge is not conclusive evidence that there is sufficient pressure at the machine. Many people do not use large enough distributing pipes to get the air pressure to the machine, and they wonder why they fail to get tight rivets.

The finishing department is the next step, and there is little to be said in detail except that the principle of *accurateness* comes in again. The material should come through in proper sequence. This is a point where a great deal of unnecessary expense can be introduced and the shop superintendent is directly responsible. See to it that the finisher, who necessarily has to work in an expensive way, is not required to do work that should be done further up in the shop. In some shops the finisher has to drive many more rivets than he should, simply because the riveting department wants to get work out fast. As the finisher drives rivets by hand the extra cost is heavy. Friction between departments costs money. The shop superintendent should see to it that all departments and men work together.

The shipper should have men enough to load his cars and check them properly. It is a great mistake to try to save money by taking one or two men from the shipping department and force one man to do three men's work.

As to the personality of the men in the shop, the yard foreman must be a man of a peculiar temperament, careful and methodical, one who cannot be bluffed into any action on his part out of the usual run which would result in confusion. The shipper must be accurate and active, and he should be genial also. He has to come in contact with the inspector probably more often than anyone else in the shop, and the shipper

who is a natural crank and does not handle the inspector properly, giving him opportunity to properly inspect the material and get the information that he requires militates a great deal against the success and good name of the shop. The shipper has also to deal with the railroad men with whom a genial temperament goes a long way.

This covers the first part of the analysis I set out to follow, the operation of a structural shop honestly. The other phase of the question is that shop operation should be carried out honorably; that is it should be carried out to make money honorably; and by honorably I mean that the shop superintendent, or the man in charge of the shop, should act fairly, squarely and openly with his employer and also with the employees. As I said before many men seem to think that the shop is operated to give them a good job and they will hang on to that job as long as they can, if necessary deceiving the owners or their immediate superiors as far as they can; and they can do so for a length of time in a good many ways unless their superiors are expert in the business and have a good deal of time to attend to it. They can deceive them by cutting down the cost of repairs, by allowing their plant, machinery, tools, equipment and buildings to get into bad condition; they can cut off what should be the maintenance expenditures and by that means make a good showing. If that is done knowingly it is done dishonestly; if it is done ignorantly it should be corrected as the result of ignorance. Another thing which is dishonorable, is to tell ones superiors that the plant is able to turn out work of some character that it is not fitted for or at a speed which they should know to be impossible. This will lead their superiors to undertake contracts which they cannot fulfill and the result is financial loss. This is a very common piece of dishonesty on the part of men in charge of fabricating shops, not ordinarily a matter of intentional dishonesty or dishonorable action; but rather through fear of the boss. The boss may tell them they ought to do it, and so they think they can do it when they should know that they cannot. I have known people to imagine that they could turn work out of a structural shop at a rate which would require the

punches to handle three or four times as much material as it was possible to punch in order to get the work out at the rate projected.

In regard to honorable action toward employees a great deal can be said. As I said before a great many do not understand the attitude of the workman, seeming to forget that he is the man who is vitally interested in seeing the work done accurately and quickly, which is the reason he spends his whole life in the shop. It is his greatest pleasure, it is a congenial occupation with nearly all the people who are engaged in it. The attitude that the man in the shop who does the work with his hands is a man to be watched and forced down, is a piece of nonsense, because he should be given a chance to develop the knowledge and skill he has for the benefit of the owners of the plant. So any attempt to cut his wages down to the lowest notch by any system that will reduce his possible earnings is a direct attack at the vital principle of the whole plant. The workman must be treated fairly if you expect him to treat the owner fairly. And the man who starts out deliberately to treat the workman unfairly is doing something that vitally affects his employer's property. This is a point that cannot be too strongly brought out. On the other hand the man in charge of a shop who is so supine that he permits some one to interfere with his management of the plant, is useless. This is a matter liable to occur at any time, some one may think that a certain class of men ought to get a certain rate or do a certain work and nothing else, which is contrary to the practices of the plant and good management. For after all it is the man who handles the iron with his naked hands who does the work and through the work of that man the profit is made for the man who owns the plant. Of course this is a very delicate subject to discuss, and I do not wish in any sense to bolster up any theories I have. It is a question of ethics rather than of engineering, but it is one that appeals to me very strongly, because when I see a large corporation deliberately attacking the wages and earnings of its employees, I begin to think of what is going to happen. If you will note the most successful corporations, the most successful plants

in this country are those which take exactly the opposite view. They allow the use of improved machinery and processes to operate for the benefit of the man who actually does the work so as to increase his wages and to better his condition, because that is the only hope they have for the perpetuation of their business.

DISCUSSION

Mr. C. M. Neeld: I have special respect for Mr. Duff's address, he being a man with the actual experience and knows whereof he speaks. Most of his principles I agree with fully.

On doing the work honestly: Nothing is more detrimental than trying to cover inferior work. It only delays trouble and the trouble generally has grown considerably when you do meet it. Reputation is worth more than the cost of replacing a few loose rivets.

On giving the men a chance: Every foreman and gang leader should be taught to teach the men under him, and so direct them as to avoid duplication. A man who only catches errors is low in efficiency. The only kind of shop work that pays is first class quality. It is cheaper in the end because it avoids these duplications spoken of by Mr. Duff. There are now many good inspectors overseeing bridge shop work who are very fair minded men, and will meet the works manager more than half way if work is conducted in a way to inspire confidence.

Mr. C. B. Albree: There is not very much that I can add. I agree with the author particularly in the special stress laid on the point that the contract should be thoroughly understood at first. There are so many misunderstandings when the contract is first undertaken that can be adjusted easily at the start, and if not adjusted make trouble not only to the fabricator but to the person ordering the work. Much of this can be prevented by the two parties getting together before the material is ordered and the work started.

Mr. W. N. Kratzer: Mr. Duff has treated the subject in its various branches very thoroughly and fully. I agree with the advisability of thoroughly understanding a contract

and what is contemplated before entering into same. By not fully understanding what is to be undertaken and what is to be produced, one is liable to get into serious trouble and expense. Mr. Duff's treatment of the various processes through the shop was very thorough.

Mr. P. E. Hunter: One thing has not been touched on that is very important, and that is the trouble caused in the shop organization due to the man at the head of the concern knowing little or nothing of the work, and the time required in different operations. From what I have heard from different shops, more trouble has been caused by expecting work to be done in an unreasonable time, or by expressing satisfaction when poor time has been made and the men knew it.

Mr. Henry M. Wilson: The man in the drafting room should understand thoroughly the work that is to be done by the shop. My experience has been that a majority of them do not know. In all cases, at least the squad foremen should go into the shop and have explained to them the manner in which the work is handled. If that cannot be done lists of the machines should be kept in the drawing room, the capacities of these machines, plans of the shop, etc., so that the draftsmen can study out the proper sequence of the work. In regard to the purchasing I think what Mr. Duff says is true, that the superintendent should be informed fully of the material purchased and time it is expected to be delivered.

Mr. J. K. Lyons: In regard to the foot trip punch and clutch, I certainly agree with the author in reference to the number of holes it will punch in a given time. In regard to methods of ordering material and what should be observed, I heartily agree with him, and think that oftentimes undue haste results in a contract with a good profit in it showing a loss when the cost is made up.

Mr. J. E. Banks: I make it a principle in engaging men to make the dollar count for the most. It is not a matter of obtaining the man for the lowest salary he will accept, but to have him do the most work for the money he gets. If men

are studied it is often found that there are among them those who are very sensitive about asking for increase of pay, and these men are often not worth as much as they might be worth because of a feeling that they are not being taken care of in this respect. Sometimes a man receiving $80 a month will not earn as much per dollar as that same man will if raised to $90 a month.

Another matter that I believe has not been directly referred to this evening, is the principle of honor as regards the customer. Might not the spirit of honor that we grant should hold between employer and employee be extended at all times to the customer also? I think that the thing we are said to be working for, the matter of profits, would be increased rather than diminished thereby, and that we would be made stronger men in our profession. The sense of honor in general requires the association of the spirit of frankness. I know of no better way to gain the good will of the customer and his representatives than this.

Mr. R. G. Manning: There is only one point I would enlarge on and that is the ordering of material by inexperienced men. Men just out of college are not supposed to know the operations the material is to undergo in the shop and therefore cannot order it intelligently. The conclusion is that they should not be required to order material. The man who orders material ought to be the man in charge of the work, who thoroughly understands the requirements both of the contract and the shop. The order is seldom checked until after the material is in the mill and usually rolled, and unless the man who does the ordering is posted in all the operations there will be mistakes. The man who comes into the drawing room without experience should only be given that work which he is capable of handling, and as his experience grows his work would grow accordingly.

Mr. Edward Godfrey: I think Mr. Duff hits it when he said the college graduate is not expected to handle the tools in the shop. I have been surprised to learn that the colleges seem to be increasing the time they give to what they term

shop practice. A student would learn more by watching an experienced workman turn a six-inch pin than in turning toys on the machines they have in college shops. What they might learn from books would be far more useful than experience in handling machines which is scarcely ever of any practical use to them.

Nearly all specifications for structural work to-day are faulty. Very important clauses are not only put in obscure places in the specifications, but are in obscure language. For example, the clause requiring reaming will be found in the middle of the specifications probably under requirements for shop work or among the requirements that pertain solely to the making of drawing and the work of the draftsman. This should be in a very prominent place in the specifications, as at the beginning under general conditions. This is also true of the clause requiring planing. This is very often indefinite and sometimes it is put in such way that it is not at all practicable to carry it out. Sometimes the requirement is that all sheared edges must be planed. Any one familiar with shop work knows this is never done. The end of a girder is never planed unless it is to be fitted to another girder. The end of a lateral angle, the edges of a gusset plate, and such parts would not be planed. Specifications should require only such planing as is necessary, and that should be stated in very clear language and should be in a place in the specifications where it will be brought to the attention of the manufacturer when he figures on the work.

THE AUTHOR: Mr. Godfrey has brought out very clearly one point I tried to make and it has been touched on by several other gentlemen, that is in regard to the knowledge draftsmen should have in ordering materials. Draftsmen can learn by observation in the shop all that is necessary for them to know in regard to shop practice without going through the physical labor necessary to perform the actual operations. This is essentially true because the draftsman, as an educated man, is taught to learn by observation and quickly assimilates information he receives by the eye or ear,

storing it in proper sequence in his mind. It would be to the great advantage of the draftsmen to have them visit the shop at frequent periods in small groups, so as not to interfere with the operation of the works, and have explained to them by some one competent to do so the purpose of each particular operation. By that means they would obtain sufficiently accurate knowledge to properly order the material. This is done in very few plants that I know of, the reason being that the few attempts made have usually been made in a bungling manner. Forty or fifty draftsmen have been turned loose in a shop and the shop superintendent and his assistants asked to show them what is being done. That number of men in one or several groups are in the way in a busy shop and many of them are ignorant of how to take care of themselves. If they are taken through the shop in small numbers by some one who is thoroughly familiar with the shop and each operation is explained to them, a few hours will so educate a college bred man in practical work that he is years ahead in knowledge of what he could get by simply listening to what filters into the drawing room. And it is to such a system that I would direct the attention of shop managers and engineers.

Another point Mr. Godfrey touched on, which is a very large subject, and possibly has no place in this discussion, is the matter of specifications. One particular point has a bearing on shop work. A great many specifications are deliberately written in uncertain terms. I have seen specifications so drawn that if the man who wrote them was educated and competent to write them, he deliberately used terms which made them uncertain and I have no doubt imagined it was a very smart thing to do; so that if he desired, the extreme of the specifications could be demanded, whereas if he did not care to do so, he could be satisfied with something a great deal less. This is a very important point. Specifications should be exact. When reamed work is specified it should be stated exactly how much material is to be taken out by the reamer. From the shop point of view the exact requirements should be on the drawings instead of putting a note on the drawings stating that all work is to be done in accordance with the

specifications of the X Y Z Railroad. Specifications should state, open holes $\frac{15}{16}$ in. reamed from $\frac{3}{4}$ in. if that is required; all sheared edges planed; all bearing parts milled, and so on, instead of expecting the shop man—and it is not one shop man but one hundred or more with whom you are dealing—to digest a number of different specifications and know exactly what is required on each contract. I have seen notes not clear and exact, put on drawings in the drafting room with the idea that they were doing a very smart thing to put the burden of proof on the shop to get the work out according to specifications instead of distinctly stating on the drawing what was required. The idea being that if the shop did not do it and the work was finished, the inspector would be forced to accept what was furnished him rather than raise the disturbance necessary to get what was specified. I cannot too strongly condemn such an idea from the point of money making, because such practices will lead to losses in the end and especially in these modern days when inspectors in nearly every case are practical, competent men. In the old days when there were very few inspectors and the work was finished, shipped and possibly erected before anybody looked at it, that method of doing business possibly might do. But to-day practically all work is put into the hands of competent inspectors and the fabricating shop that deliberately sets out to fool the inspectors will only be fooling themselves.

MEMOIR

JOSHUA RHODES.

Born March 19, 1824, in London, England.

Died January 5, 1909, at his home in Western Avenue, Pittsburgh.

Mr. Rhodes was a Charter Member of the Society.

In 1828 his parents came to America, settling in Pittsburgh when he was six years old. For seventy-nine years he was a resident of this city. At the age of twelve his parents died, when he began his business career as errand boy in a grocery store, a few years later owning a store in First Avenue, near Smithfield Street. With James Verner he established a cracker factory, later selling his interest to become the pioneer in the confectionery business in Western Pennsylvania. The business he established is still being conducted by Reymer & Bros. After a number of business ventures he bought, with his former partner, James Verner, an old pipe mill on Herrs Island, which was the beginning of his most successful business enterprise. This business eventually became the Pennsylvania Tube Company and it was while he was its head that he developed the manufacture of large sized steel pipe, of which branch of the industry he was the originator. Later he organized the National Tube Company, being made president, remaining at the head of this corporation until it was sold to the United States Steel Corporation. This marked Mr. Rhodes' retirement from active manufacturing business, as he devoted his time latterly to quiet pursuits and financial investments.

Mr. Rhodes was interested in the first horse car railway in Pittsburgh, was interested in building many of the original street railway lines and later in their electrification. He was at one time president of the Consolidated Traction Company, and took an active part in bringing together the interests that formed the Pittsburgh Railways Company.

Mr. Rhodes organized the Apollo Iron and Steel Company, and was interested in the formation of the American Sheet Steel Company, which was afterward absorbed by the United States Steel Corporation.

In the various consolidations of steel and traction interests, Mr. Rhodes' counsel was sought and his rare ability in bringing together conflicting interests, aided largely in effecting many consolidations.

Mr. Rhodes was probably at one time a member of more boards of directors than any other man in Pittsburgh. His financial interests were very extensive and there was scarcely a bank or trust company of importance in which he was not interested.

For many years he was a member of the First Presbyterian Church. He was unassuming in his charities, which were of wide scope, and he was a man blessed with many friends. He is survived by a widow, one son, William B., and two daughters, Mary H. and Anna L. Rhodes.

ARC WELDING

By C. B. Auel*

Though this paper has for its title "Arc Welding," it may not be amiss to describe very briefly the several other processes of electric welding; and thus, while incidentally presenting a slightly broader view of the general subject, give at the same time a better idea of the particular field of application for Arc welding.

There are four distinct processes of electric welding, known respectively as the Thomson, the Zerener, the La Grange-Hoho and the Benardos, these taking their names from the persons who either originated or else had most to do with developing them.

In the Thomson, or as it is sometimes called, the incandescent or resistance method, the two metals to be welded are clamped to the two terminals of an electric circuit and carefully butted together. When the circuit is completed, current flows through the abutting metals, heating them to fusion. As the fusing temperature is reached, they are automatically forced into each other, as it were, thus uniting perfectly. The resulting joint is always accompanied by a shoulder or fin, which, however, is easily removed, usually by a hand file, though sometimes an automatic hammer or roll is employed. The apparatus, one form of which is shown in Fig. 1, consists of a transformer, in size from 1 to 100 K. W. or more, depending upon the class of work to be done. The primary of the transformer may be designed for operation at any one of the usual voltages and frequencies, the secondary being arranged to give a very large current at a very low voltage and being further provided with terminals in the shape of heavy clamps, sometimes water-cooled, in which are secured the metals to be welded. Variation of output is obtained by means of

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* Manager of Railway and Control Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh.

switches or a choke coil in the primary circuit. The method just described is used for a variety of purposes, such as the uniting of wires, rods or bars of similar or even of dissimilar metals, the making of tires and cylinders, the putting on of heads to bolt and screw bodies, the joining of rails, etc.

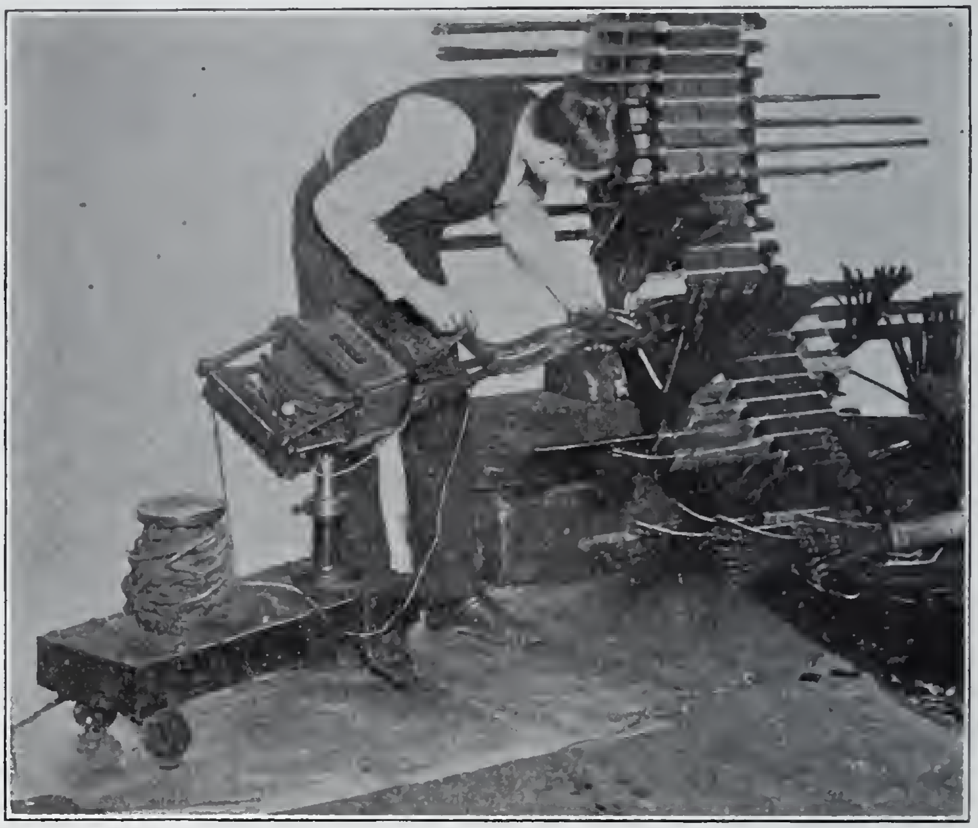

Fig. 1. Thomson, or Incandescent, Electric Welding Apparatus.

In the Zerener or electric blow-pipe process, an arc is sprung between two carbons and caused by means of an electro-magnet to impinge upon the metals to be welded. The metals are thus brought to a state of fusion at the point of contact with the arc. The apparatus employed (Fig. 2, taken from Glaser's Annalen) is much like certain types of direct current flaming arc lamps, the carbons approaching each other at an angle, and further resembling them in being provided with a magnet for blowing the arc downwards, shaping it, however, into more or less of a pencil point instead of spreading it out as is done in the lamps. The work to be welded is so placed that the arc may be directed upon it, the blow-pipe being moved by hand either towards, away from, or parallel to the work, as occasion makes necessary. Owing to the gen-

Fig 2. Zerener or Electric Blow-pipe Apparatus.

eral construction of the apparatus, which does not lend itself to the carrying of large currents, and to the difficulty in properly regulating the arc, the process is confined to a rather narrow range of small work of the rougher kind, such as the welding of small castings and wrot iron plates.

In the La Grange-Hoho process, otherwise known as the water-pail forge, Fig. 3, the metals to be welded or forged are fastened to the negative terminal of an electric circuit, the

positive terminal being placed in a wooden tank containing a suitable solution. Upon completing the circuit by inserting in the solution the metals to be welded or forged, they are rapidly brought to the proper temperature, when they are then withdrawn and welded together or forged to shape in the customary manner. The process is adapted to small and simple work, preferably of wrot iron, and such as can be readily manipulated by hand.

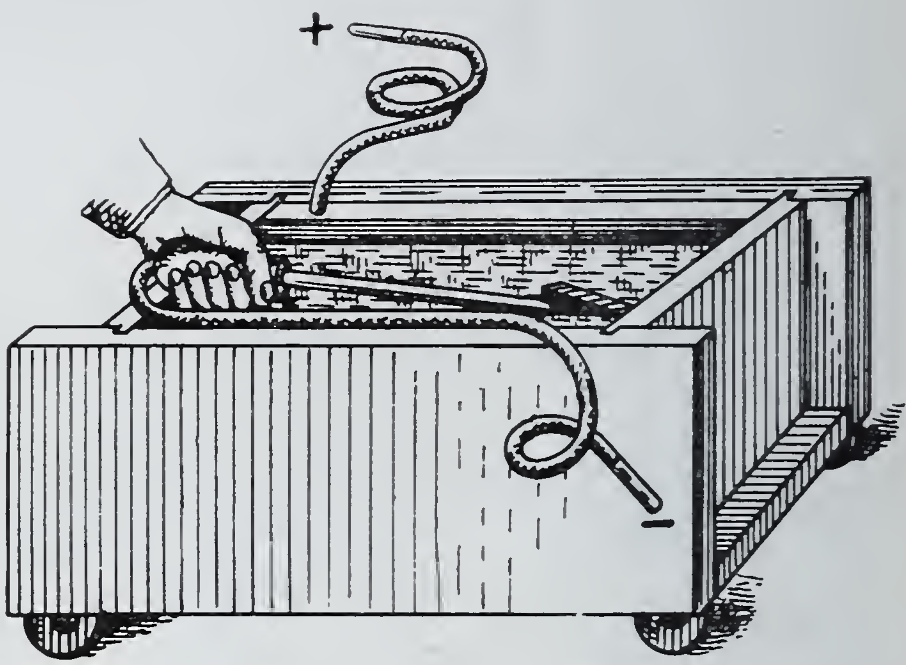

Fig. 3. La Grange-Hoho Electric Welding Apparatus.

It may be mentioned in passing that all three of these processes are used for soldering as well as for welding, it being simply a matter of applying less heat.

In the Benardos or arc welding process, Fig. 4, the metal to be welded forms one terminal of a direct current circuit, a carbon electrode the other. By touching the carbon to the metal and instantly withdrawing it a certain distance, an arc is sprung between the terminals. Through the medium of the arc, which has a temperature between 3500 and 4000 deg. cent., the metal may be either entirely melted away, molded into a different shape, or fused to another piece of metal as desired.

A complete outfit for arc welding consists of a direct current supply with its controlling apparatus, a stock of carbon electrodes of various diameters, fire-clay, or carbon blocks for molding the metal, a flux, and material for filling purposes Owing to the intense glare of the arc, the work must be done

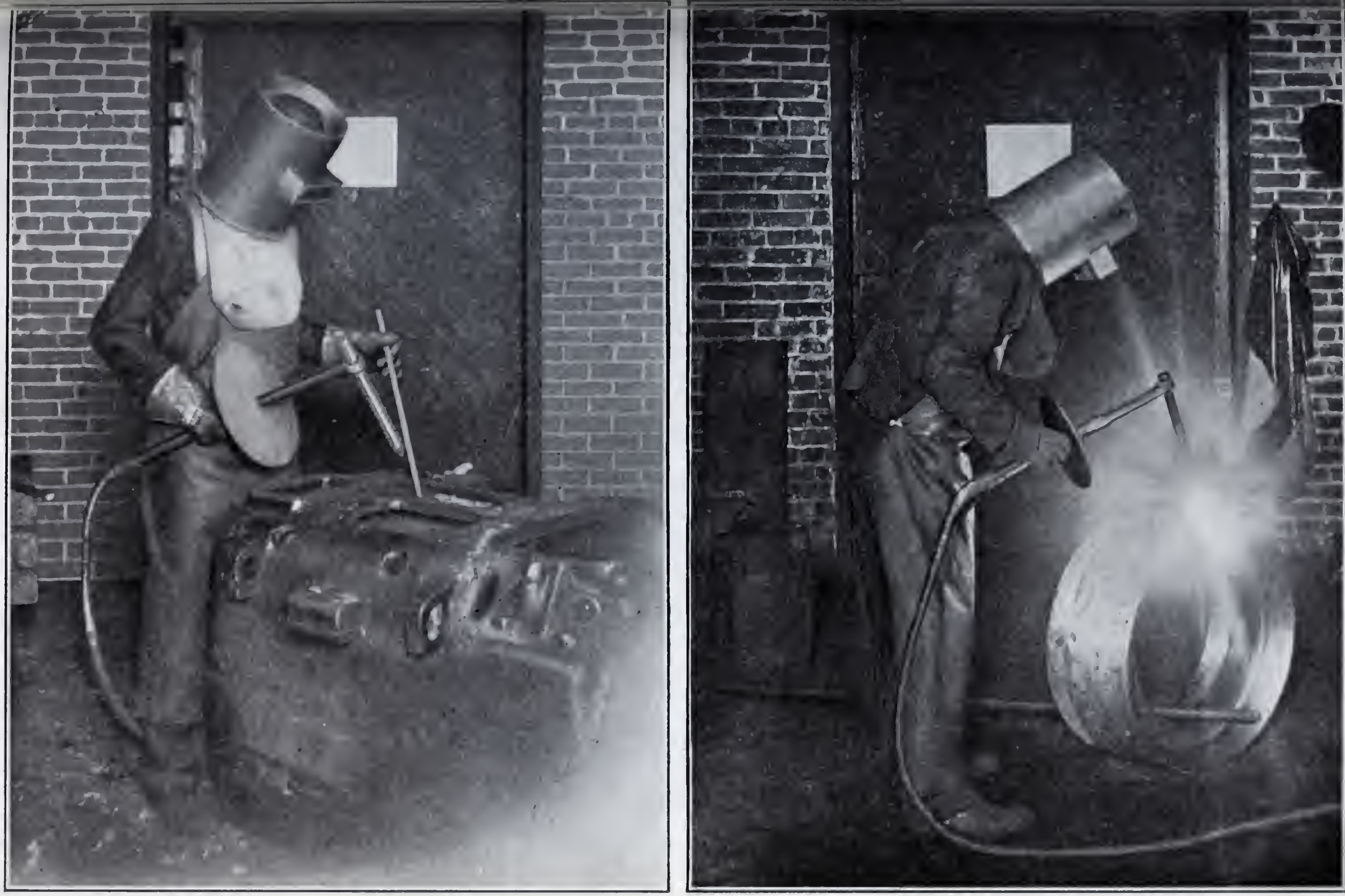

Fig. 4. Benardos or Arc Welding Apparatus.

in an enclosure in order not to interfere with other work in the immediate vicinity.

The operator, too, must be thoroughly protected over the entire person. It is not sufficient, as with oxy-acetylene welding, simply to shield the eyes with a pair of colored glasses. Exposure to the direct rays of the arc produces an irritation of the skin quite similar to sunburn, the skin reddening and subsequently peeling, being accompanied by a stinging or

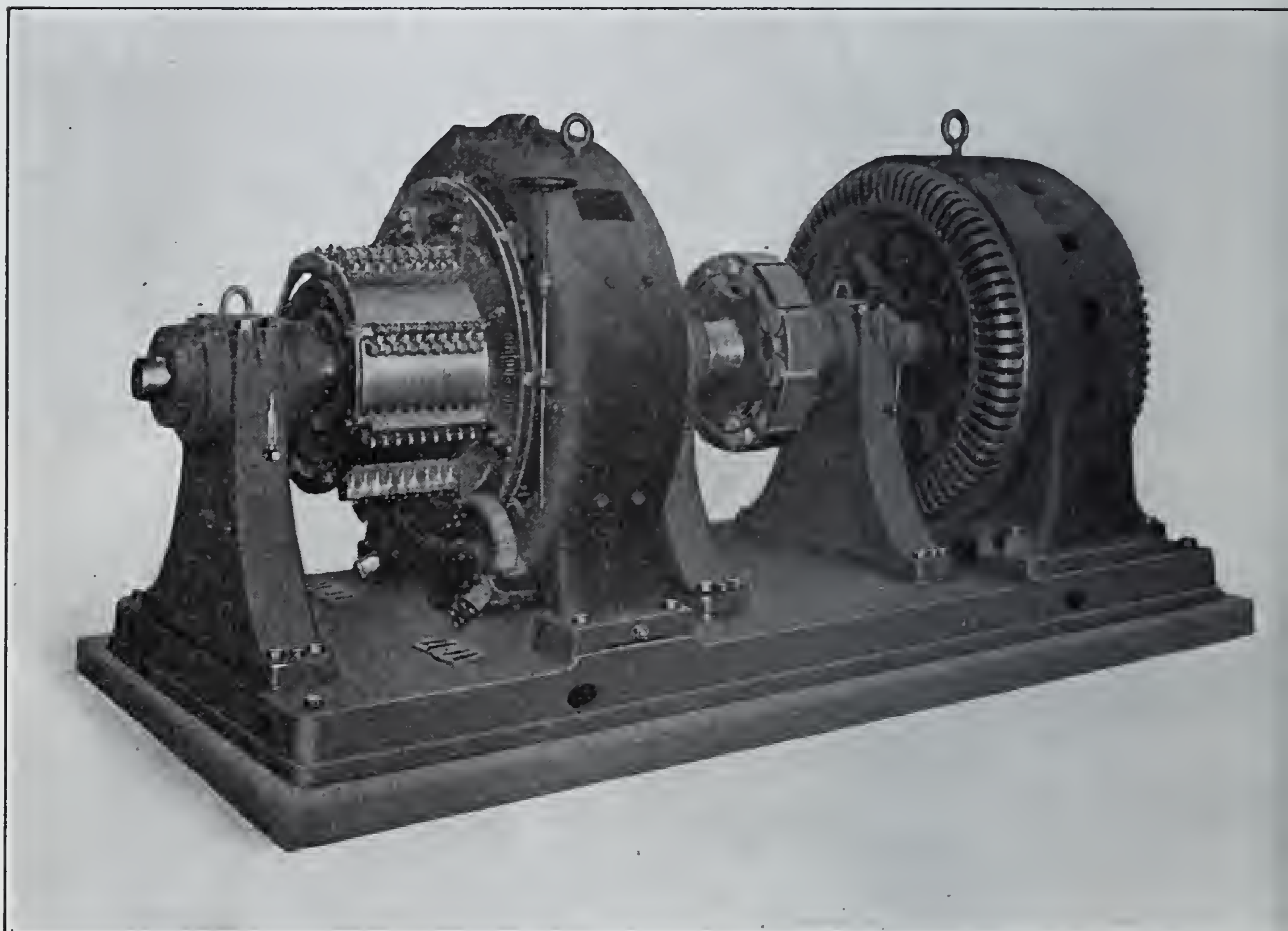

Fig. 5. Motor-Generator Set with Flexible Coupling.

burning sensation over the area of the exposed surface; but with, however, no more serious consequences. For this reason a covering either of canvas or stove-pipe and fitted with a projecting window of thick colored glass is usually worn over the head, while the hands and and wrists are protected by gauntletted gloves of buck or pig skin. In making the window for the hood it is advisable to use two pieces of glass, one of red and one of blue, or one of red and one of green, as the

combination is more satisfactory than a single color. Both the canvas and the stove-pipe are open to objection, the former on account of the lack of ventilation, the latter owing to the possibility of touching the carbon electrode to it in a moment of carelessness and thus receiving a shock. Care should be taken to have the window of the hood project a little, as the glass will, in time, become quite hot, and if too close to the eyes will inflame them. If preferred, a wooden shield properly fitted with glass and which is held in the hand may be used: but it, too, has an objection in that it requires the constant use of one hand.

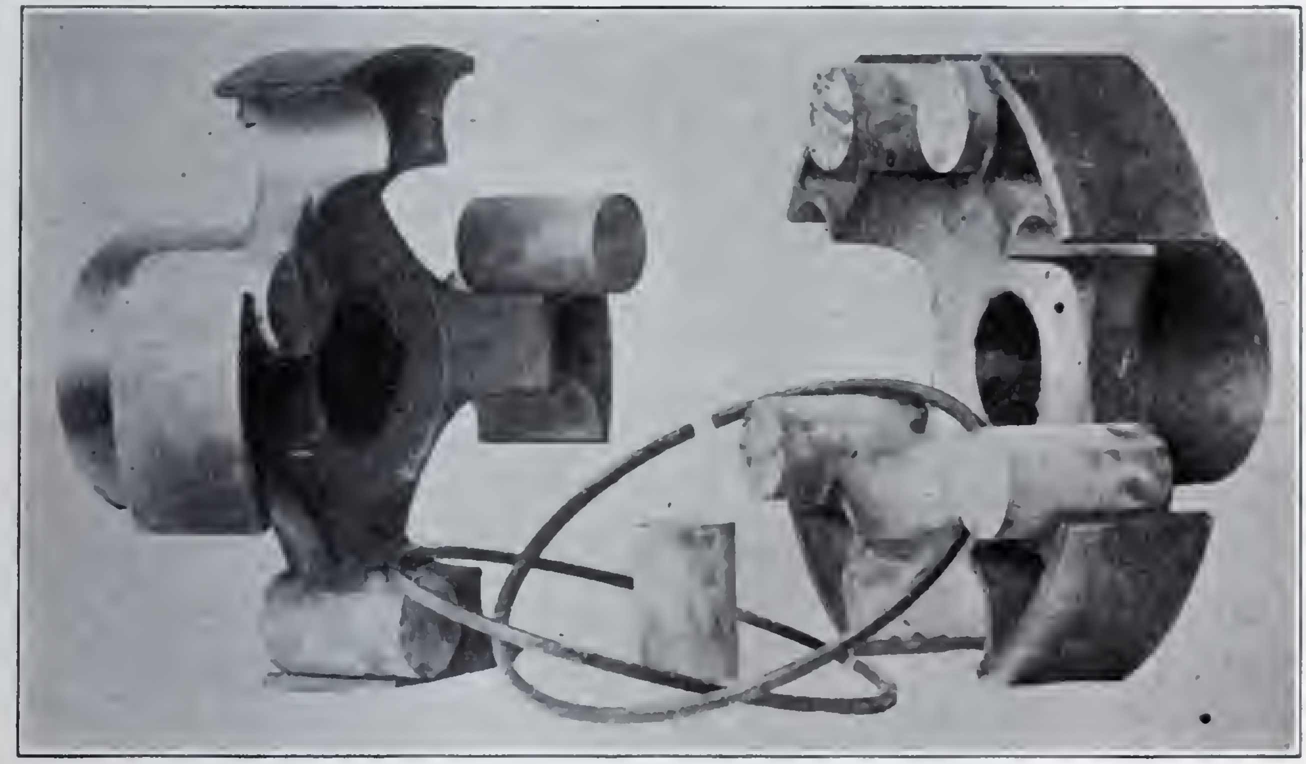

Fig. 6. Details of Flexible Covering.

The necessary direct current may be obtained in a variety of ways, either from a 100 volt independently driven dynamo, from a similar public supply circuit, or from a battery operated in conjunction with a dynamo or other supply circuit; or current may even be obtained from a higher voltage supply, if this is the only kind available, though the last is very wasteful and can be recommended only where the work to be done is so infrequent as not to warrant one of the other methods being employed. In general, the supply should be of not less than 75 to 100 K. W. The dynamo may be shunt or compound

wound, preferably the latter, and if direct connected, a flexible coupling should be used in order to prevent burning out of the armature. Fig. 5 shows a motor driven dynamo of this kind, of 200 K. W. capacity, the flexible coupling consisting of two interlocking arms separated by solid rubber cylinders, one arm being rigidly connected to the motor, the other to the dynamo. Fig. 6 shows the coupling in detail.

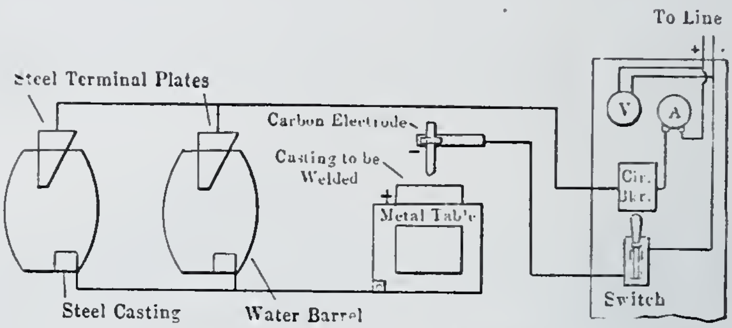

Fig. 7. Diagram of Arc Welding Circuit.

The circuit for the control of the current may be arranged in either of two ways. The first of these is shown diagrammatically in Fig. 7. It will be observed that one leg of the circuit leads from the switchboard through a circuit-breaker to the main rheostat which, in this case, consists of two water barrels. These are provided with pulleys and counter-weights, by means of which the distance between the terminal plates may be varied and the resistance in the circuit increased or decreased accordingly. From the rheostat the circuit is continued to a metal table which forms the positive terminal. The metal to be welded may be laid upon this table, especially if it has a flat, smooth surface and is not too large; otherwise it may be found more convenient to fasten the cable from the rheostat directly to it. The other leg of the circuit leads from the switchboard through a single-pole switch to the carbon electrode. While water-barrels (Fig. 8) serve as rheostats fairly well, the objections to them are that when the plant is worked very hard, the water will occasionally boil over, necessitating a stoppage of the work to allow the water to cool; further, the bands on the barrels rust away, thus requiring new barrels every few months. Grid rheostats (Fig. 9) are therefore frequently used instead. They are provided with

several switches by means of which the resistance may be graduated.

A second arrangement of circuit is shown in Fig. 10. It differs from the first in having a relay which operates to cut out a part, or even the whole, of the main rheostat as soon as the circuit is completed. Where the cost of current is an appreciable factor, this is a convenient arrangement, as the loss through the main rheostat may be reduced or eliminated.

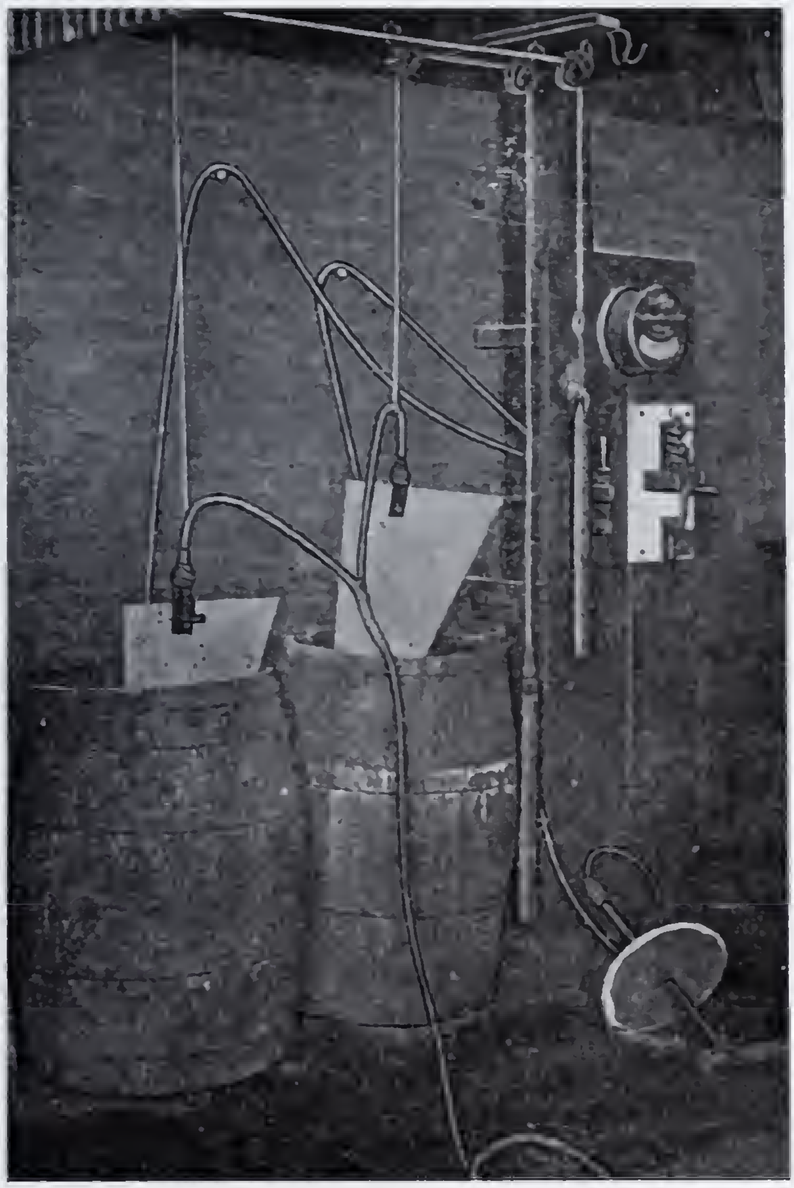

Fig. 8. Water Barrel Rheostats.

One kind of electrode, illustrated by Fig. 11, consists of an insulated metallic handle provided with a properly clamped carbon, which forms the negative terminal of the circuit. The carbon used will vary from ¼ to 1½ in. diameter by 6 in. to 12 in. long. It should be hard and solid (not cored), and in

burning away should leave a rounded end instead of a pencil point. The carbon is clamped about midway simply to reduce the resistance somewhat.

In another kind of electrode a button is provided which, when pressed, brings into action two solenoids; these in turn closing the main circuit, but keep it closed only as long as the button is pressed down by the finger. The advantage of this feature is that short circuits are guarded against in case the electrode is accidentally dropped or carelessly set down.

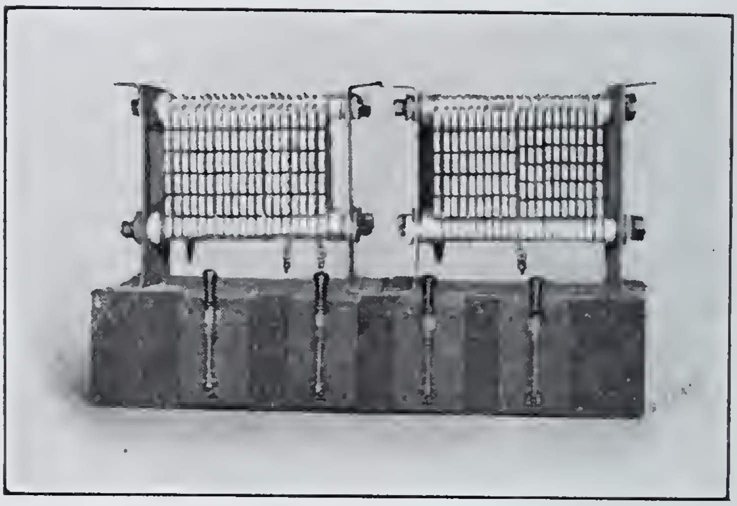

Fig. 9. Grid Rheostats.

In preparing for a weld (Fig. 12) the piece to be welded may, as previously stated, be laid upon the table or the positive terminal may be fastened directly to it. Emphasis is laid upon the necessity of making the piece to be welded the positive terminal, so that the current will flow to instead of from the carbon electrode. Should the direction of flow be reversed, carbon will the more readily enter the piece being welded, thus producing a very hard weld and one difficult, if not impossible, to machine. The plates in the water barrels are next placed at what is deemed to be the correct distance apart to give the necessary resistance; or, if grid rheostats are used, the same result is accomplished by adjusting the switches, each of which cuts into or out of the circuit, a certain number of grids. The circuit-breaker and the single-pole switch are then closed, after which the operator places himself in position, with the carbon electrode in one hand and having within reach of the other the flux and the material to be used

as filler. He next pulls the hood down over his head, touches the carbon electrode to the piece to be welded and instantly withdraws it to a distance of two inches or more. The arc thus produced is allowed to play upon the piece, being given a rotary motion by the hand, until the metal commences to boil. Should the arc cause trouble by frequently going out, or if, on the other hand, it prove too intense, the resistance in the circuit must be altered accordingly. The rotary motion enables a considerable area of the surface of the metal in the vicinity of the weld to be heated, thus preventing it from cooling too rapidly, with the con-

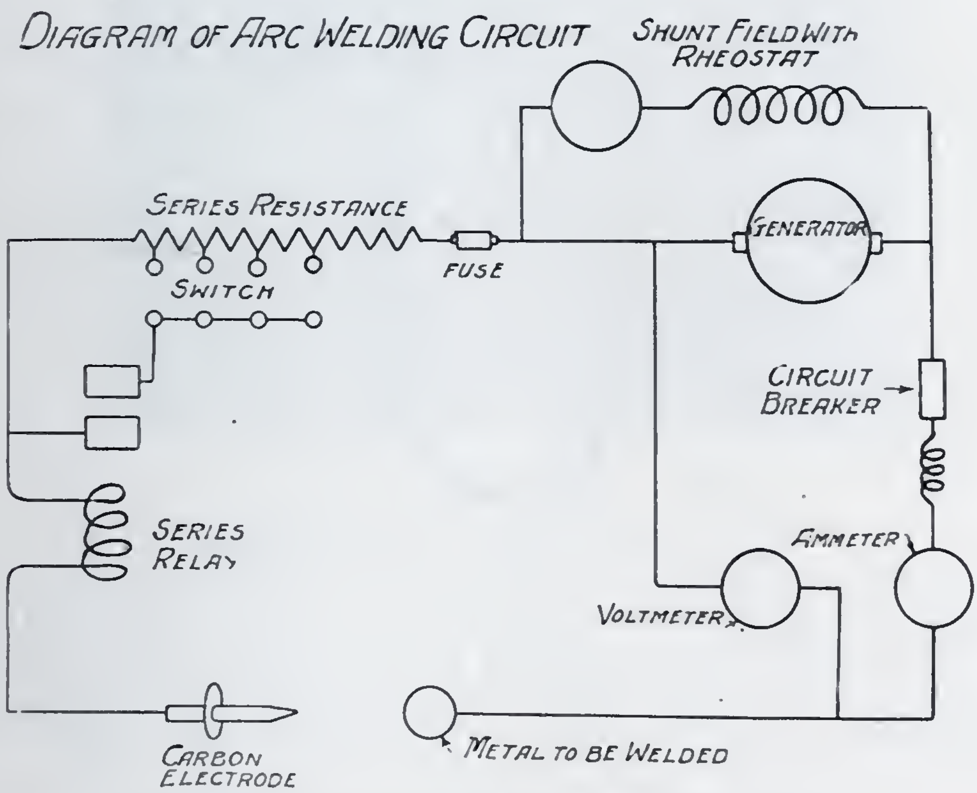

Fig 10. Diagram of Arc Welding Circuit.

sequent danger of cracking or producing hard weld. When the fusing temperature is reached, the filler and the flux are put into the boiling metal, a little at a time, the arc meanwhile being continued until the weld is completed. Hammering of the weld during the process of cooling will be found advantageous as giving the metal a closer grain. It is advisable, whenever possible, to make the weld during one continuous application of the arc. Not only will the weld thus be made more quickly, but there will be no tendency for scale to form and so assist in causing a hard weld. When, however,

it is necessary to make several applications of the arc, care should be taken to remove the scale by brushing with a stiff wire brush. It is equally necessary to have the metal quite clean before commencing a weld; this may be accomplished by chipping, or the piece may be tilted and the arc applied until the dirt or slag has melted and run off by gravity.

Fig. 11. Electrode for Arc Welding.

In the welding of wrot iron or steel, the filling material may be soft iron rod, punched iron scrap, or broken bits of steel castings. A very good flux consists of a mixture of 15 to 25 per cent of red oxide of iron ($Fe_2\ O_3$) and 85 to 75 per cent of borax ($Na_2\ Bo_4\ O_7 + 5\ H_2\ O$). Any carbon which may have been introduced into the weld unites with the oxygen in the flux to form CO_2 gas, leaving behind soft iron. Should, however, this CO_2 gas not be wholly removed, it will cause sponginess in the metal. The borax simply assists in preventing oxidation by spreading over the weld and keeping out the air. When building on a lug, a mold is made of fire-clay or carbon-blocks in order to give the metal the desired shape. Figs. 13, 14 and 15 show a cast steel bearing cap, before and after being provided with a lug and the way in which the mold is prepared.

Fig. 12. Preparing to Weld.

In welding cast or malleable iron, the metal must be slowly preheated to a cherry red, the weld being made while in this condition, and the piece then allowed to cool equally slowly. The same flux as for wrot iron or steel, and filling material of soft iron rod, punched iron, copper or special cast iron may be used. For small work, it is preferable to have a gas furnace, opening from the top, and if possible to make the weld without removing the casting from the furnace. For

Fig. 13
Steel Casting Requiring Lug.

Fig. 14
Steel Casting Ready for Welding.

Fig. 15
Steel Casting After Welding.

large work, a temporary furnace may be built entirely around the casting, ports being provided which at the proper time can be uncovered and through which the carbon electrodes can be inserted and the welding done.

When welding a brass or zinc casting, the piece must be supported in such manner that it will not lose its shape, and borax should be used as a flux to reduce oxidation.

Fig. 16. Steel Casting with Sink Head.

Welds made in iron or steel by the electric arc are sometimes found to be extremely hard. Where there is no machining to be done, this feature is of little moment, and occasionally may even prove of advantage. Where, however, machining is required, a hard weld is a serious matter, and, while annealing may be resorted to, re-making the weld will usually be found preferable. It may be taken for granted that when a hard weld is encountered, it is due to failure to observe one or more of the several precautions already outlined and

which may perhaps be summarized at this point to advantage as follows:

1° The positive terminal should always be fastened to the metal to be welded—the negative terminal to the carbon electrode.

2° The arc should be as long as possible.

3° The weld should be made with the fewest possible applications of the arc.

4° The arc should not be concentrated on one spot, but be given a rotary motion and cover as large an area as possible.

5° The metal to be welded should be freed from dirt and slag before commencing to weld and subsequently kept free.

6° A suitable flux should be judiciously used.

Fig. 17. Steel Plate with Holes Bored by Electric Arc.

It is interesting to compare the strength of fire-welded with arc-welded iron and steel bars. In a paper by Mr. Samuel MacCarthy on "Steel Plates, Pipes and Fittings, and Benardos Arc Welding in Connection Therewith," read before the Institution of Mechanical Engineers, England, the results of a series of tests were given which are reproduced in Table 1. The bars were all scarf-welded, the scarf ranging from 1¼ in. to 1½ in. It will be seen that there is a difference of about 18½ per cent in favor of the arc welded bars, and it is of

further interest to observe that the strengths of the welds range from 73.6 to 92.0 per cent of that of the original material.

TABLE 1. MAIN RESULTS OF TESTS OF FIRE-WELDED COMPARED WITH ELECTRIC-WELDED BARS

BRAND AND SIZE F = Fire-Welded E = Electric-Welded			Ultimate Tensile Strength Per sq. in. T		Contraction of Area at Fracture C		Extension in 10 inches		Ratio of Weld to Solid		Figure of Merit T × C	
Brand	Inches		Tons		Per Cent		Per Cent		Per Cent			
Lowmoor Iron	2 x $\frac{3}{16}$	F	20.3	......	15.2	......	7.3	......	77.9	....	308	......
		E	......	21.1	......	17.3	......	7.3	......	81.1	......	365
Lowmoor Iron	2 x $\frac{5}{16}$	F	21.5	......	22.3	......	11.3	......	90.7	......	479	......
		E	......	21.8	. ....	20.7	......	9.7	.....	91.8	......	451
Netherton Best Iron	2 x ¼	F	18.4	......	10.1	......	3.4	.....	84.4	......	185	.... .
		E	....	20.1	......	10.8	......	4.5	. ....	92.0	......	217
Parkgate Steel	2 x ⅛	F	20.9	......	9.3	......	1.9	......	69.1	......	194	......
		E	.....	22.3	... .	18.4	.....	3.8	....	73.6	......	410
Parkgate Steel	2 x ½	F	20.4	......	15.9	......	8.1	......	82.3	.....	324	.....
		E		21.0		15.4		7.3		86.4	.....	323
											1490	1766

$$\frac{\text{Average of Electric-Welded Bars} = 1766}{\text{Average of Fire-Welded Bars} = 1490} = 118.5 \text{ per cent.}$$

Besides the welding of metals the Benardos or Arc welding process may sometimes be employed with advantage along quite different lines, as for example, in cutting away surplus metal, also in removing sink heads from castings, Fig. 16; or for boring holes in wrot iron and steel plates, Fig. 17; for flanging pipes; for opening the tap hole in furnaces, etc. In Fig. 18 is shown a casting which was received from the foundry without the strut supporting the bearing bracket. This was supplied by welding on a heavy wrot iron support.

To give exact data as to the time required for making welds, the current consumption, size of welds, etc., is from the nature of the work almost impossible. Tables 2, 3 and 4 will, however, afford some idea of these items and are given as approximations only.

TABLE 2. BERNARDO'S PROCESS, FILLING DRILLED HOLE IN AXLE CAP

Line Volts	Amperes	Volts across Rheostat	Volts across Arc including Carbon
126 (open circuit)	.....	...	...
102	550	38	63
102	500	36	65
102	550	39	61
98	600	42	53
97	650	44	51
97	650	45	50
102	600	42	58

Size of hole = 1¼ in. diameter by 2 in. deep. Size of carbon = 1½ in. by 6 in. Time = 56 seconds.

TABLE 3. BERNARDO'S PROCESS, REMOVING SINK HEAD FROM AXLE CAP

Line Volts	Amperes	Volts across Rheostat	Volts across Arc including Carbon
120 (open circuit)	.....	...	...
95	600	34	62
98	650	30	67
100	600	31	67
95	850 (kick)	30	64
100	850	30	71
100	850 (kick)	35	63

Cross-section of sink head = 2½ by 6 in. Size of carbon = 1½ by 6 in. Time = 4 minutes, 45 seconds.

TABLE 4. BERNARDO'S PROCESS, BURNING HOLE IN WROT-IRON PLATE

Line Volts	Amperes	Volts across Rheostat	Volts across Arc including Carbon
120 (open circuit)	......	...	...
98	430	23	72
102	400	22	81
104	370	20	86
85	1000 (kick)	24	60
87	1000 (kick)	35	63

Size of hole = 1¾ in. diameter by 1½ in. deep. Size of carbon = 1½ by 6 in. Time = 3 minutes, 30 seconds (includes 45 seconds for reversing plate).

The query has doubtless arisen in the minds of many among you as to how arc welding compares with the oxy-acetylene process. The two processes would seem to be complementary rather than antagonistic, arc welding having as its particular field heavier and, if it may be so called without

Fig. 18. Casting with Bracket Support Welded On.

misinterpretation, rougher work; while the oxy-acetylene process is more adapted to small work, castings, shafts and sheet metals, including the cutting of thin sheets, the close regulation of the flame permitting a delicacy of manipulation impossible with the arc.

TABLE 5

Current in Amperes	Length of Arc .039 in.	Length of Arc .117 in.	Length of Arc .195 in.	Length of Arc .275 in
4..................	34.3	35.9	37.4	39
8..................	32.8	33.6	34.3	35.1
12..................	32.3	32.8	33.3	33.8
16..................	......	......	32.8	33.2
20..................	......	......	......	32.8

Positive Carbon Voltage Drop—Solid positive carbon diameter, 7/16. Solid negative carbon diameter, 3/8.

TABLE 6

Current in Amperes	P. D. in Volts
4	11
8	9.3
12	8.7
16	8.45
20	8.3

Negative Carbon Voltage Drop—Solid positive carbon diameter, 7/16 in. Solid negative carbon diameter, 3/8 in.

DISCUSSION

MR. C. PIRTLE: Mr. Auel has covered the ground so thoroughly, so far as the application of arc welding to ordinary repairing of steel castings is concened, that I do not know of anything to add. I might state that I had sent down here some samples of cast iron which we have succeeded in welding recently without any preheating, the iron being in a cold state exactly as a steel casting would be. Also two or three brass castings in which holes have been filled up.

In making the statement that we had been successful in welding cast iron withont any preheating, I regret that I cannot tell you exactly how it was done, as at the present time it is in more or less of an experimental stage, and possibly is patentable. Later on we will be glad to give out the information.

Our interest in arc welding is not so much in the work that has been done, as in the manufacture of the apparatus to do the work. I would say in this connection that a motor-generator set giving a low voltage source of supply, should by all means be used. As a rule 220 or 110 volts is used, which is very inefficient, and not enough current is available at 220 or 110 volts from the ordinary industrial plant to do good work. Nothing to my mind has kept arc welding back so much as trying to operate with too little current. Mr. Auel's tables show from 350 or 400 up to 1000 amperes and this is the range of current necessary to meet all conditions. Very little welding work can be done with a machine that will not give you 600 amperes with safety.

The arc welders which we have sold are being used mostly in steel foundries, but several are used in other plants and for work which is unusual, though I am not at liberty to speak definitely of these, because the users consider them "shop kinks." For instance, one user is making the side seam and putting heads into hot water boilers and low pressure steam boilers. He is putting these on the market and guaranteeing them. There was one case of cutting material by the electric arc, in which about thirty slag pots had been made, which would not clear the ground by about ½ in. It was found to be partly due to a mistake in the drawing and partly to the sag of the mold, which made the bottom of the pot too thick. The casting weighed in the neighborhood of 20 000 lb., and they took about 1½ in. off the bottom in a short time and in a very efficient way with the arc. The carbon used was 2½ in. diameter and the current in that particular application was about 1200 amperes.

There is another instance of the use of the arc for cutting structural material. It was used to break up the Ferris Wheel. When they blew the props out from under it with dynamite, it was supposed to fall over on its side. Instead, the big main axle came straight down, and since the tension members were round wrot iron, they simply doubled up like a collapsed bicycle wheel, and it was a bad tangle. They got in there with an arc welder and made short work of the wheel, though there were a good many tons of iron in it.

There is one thing Mr. Auel did not speak of, on which I would like some information, and that is the repairing of shrinkage cracks. We have found that very difficult to do. Of course, in heating and cooling practically the same stresses are brought into play that caused the first cracks, and they draw the cracks again. We have been successful in repairing shrinkage cracks by preheating the metal just as we would ordinarily weld cast iron in making a repair and then cooling very slowly. Is there any short cut to hasten that process?

Mr. G. H. Wood: I have no doubt that many of the engineers present are familiar with the usual methods em-

ployed in opening the tap hole of blast furnaces after the iron has become chilled.

At Carrie Furnaces we make use of a simple but effective application of the electric arc. Although not original with us, we have used this method for several years, and it will be the object of my talk to tell you how this method is used under the actual working conditions at our plant.

We have a double pole, single throw knife switch permanently located at each furnace with the positive terminal clamped firmly to the structural part of the furnace and the negative terminal connected, through a small bank of grid resistance submerged in a barrel of water, to the burner, which consists of a carbon 2 in. diameter by 48 in. long, supported by a short length of 2 in. pipe with a wooden handle. When assembled, the burner is about 10 ft. long, thus bringing the operator at such a distance from his work that he can see plainly, and also be able to get away should there be a sudden rush of metal. The operator is provided with a box hood supported from the shoulders, ventilated at top and bottom, and fitted with red and blue glasses for the protection of the eyes and face.

Being thus equipped, the operator draws an arc on the chilled iron in the tap hole, using a line potential of 250 volts and a direct current of 800 amperes. With a 2 in. arc and the above conditions of voltage and current, the burning will proceed at the rate of 30 in. per hour. After the furnacemen have exhausted all other mechanical means, it is possible to free iron within 45 min. by using the burner.

We find that the burner can be used to advantage for many other kinds of work around the furnaces. Sometimes, after a furnace has had a bottom slip, some of the tuyeres are filled with chilled iron and cinder. The burner is then put at work, and the tuyere is soon opened. Care has to be taken lest the side of the tuyere is burned in the operation. Oftentimes cinder is encountered, and since it is a non-conductor the arc is broken. To get through the cinder, a sharp iron bar is driven till it strikes the iron, and then blocked to one side to allow the burner to pass, so as to burn off the bar as

far in as possible. Then the burning continues along the iron point embedded in the cinder until the iron itself is reached.

In burning out tuyeres, care has to be exercised when the chilled iron is burned through, as the hot blast, which is coming in through the other tuyeres, will blow hot metal and cinder out on the operator. To avoid such an occurrence, the burning is stopped as soon as the iron becomes somewhat soft. Then the hot blast is put on, and the tuyere is soon freed of any iron that may be left in it.

In tearing down the bosh of a furnace, preparatory to relining, we use the burner to burn off the bosh rings, thereby saving time and expense.

Oftentimes, the removal of the salamander is the cause of much delay. If it is too hard to be drilled by rock drills, we use a burner. The brick work is cleared away from around it, and the burning is done from the side with an inward and slightly upward direction, so that the fused iron can run out. To do this, the burner is shortened so that the operator may get in beside the salamander.

We had trouble with the clamping "I" beam on a car tipple. It was too long, and bent the handles on the cars as it clamped them ready to be dumped. This was an extra heavy 24 in. "I" beam, and we burned the end off in 12 minutes.

Recently a spur from the railroad track was needed to enter the side of a new extension to the power house. This site was surrounded with sheet piling which projected above the ground. We put a burner at work, and at the rate of four minutes per 12 in. pile, soon cleared a space for the track.

Although with a 250 volt circuit we are able to get any length of arc up to 10 in., we find that we obtain the best results with about a 2 in. arc and a current of 800 amperes, using a low resistance of probably 0.16 ohm.

THE ELECTRIC CARBON ARC*

BY C. E. STEPHENS

At the present time there is available very little data giving results of experiments with the electric arc where materials other than carbon have been used for electrodes.

* Read by H. D. James in the author's absence.

I propose, however, to point out a few of the characteristics of the electric carbon arc which may be of interest in arc welding processes. In this connection you will note that in all cases, comparatively small values of current have been used, and that with larger values of current, and iron electrodes, the result would, no doubt, be somewhat different.

The initial step in any welding process being the raising of the parts to the proper temperature, it follows that a certain amount of heat at the proper points is necessary and an economical application of same highly desirable. The electric arc for welding processes has quite an extended application since it has the highest temperature known to science; it is comparatively easy to handle, and the characteristic distribution of the energy is such that it can be quickly and economically applied at the desired point.

As has been pointed out in the preceding paper this evening, the electric arc has its most efficient application in what is known as the "Benardos Arc Welding Process." The apparatus required for this process consists of a generator, a negative electrode, and some form of resistance, together with necessary auxiliary apparatus for conveniently controlling same. In commercial service, the different operations, classes of work and the consequent quality of material in the positive electrode, vary to such an extent that it is impossible to select an outfit which can be operated by an unskilled man, and at the same time be universally operated at its highest efficiency. It will probably be of interest, however, to discuss the conditions obtaining when the energy delivered by the generator is utilized in the most economical manner.

With solid carbons, if the length of the arc is fixed, the resistance of the arc decreases with an increase of current, and increases with a decrease of current. With the smallest current flowing the resistance is the highest; as the current is increased the resistance falls (at first very rapidly and then more and more slowly), until a point is reached when the arc will "hiss". With a given range of current, the resistance changes much more with a long arc than with a short one. The ratio of change of resistance to change of current is

greater the smaller the current and the longer the arc. It follows, therefore, that with a constant generator potential it is impossible to maintain an arc without connecting a certain amount of resistance in series with it. Since the voltage drop across the resistance increases with an increase in current and vice versa, it serves as a ballast for the arc, neutralizing the voltage changes in the arc and the circuit is stable. The amount of external resistance required varies with the current and length of arc. The minimum value of this resistance, for a given current and length of arc, determines the least E. M. F. in the generator that will maintain the given current through the given length of arc.

Assuming that a particular weld requires the dissipation of a certain amount of energy in the arc, it is apparent that there is a ratio between the energy in the arc, the energy in the external resistance, and the generator voltage, at which ratio the material to be welded is heated in the most efficient manner. If the E. M. F. of the generator, the external resistance and the qualityy of the electrode be fixed, the maximum length of arc and the minimum current that can be maintained can be found in terms of that E. M. F. and resistance. If the E. M. F. of the generator, the length of the arc and the quality of electrode be fixed, the minimum external resistance that can be used, and the minimum current that will flow can be found in terms of E. M. F. and the length of the arc. If the E. M. F. of the generator, the current and quality of electrode be fixed, the maximum external resistance that can be used and the maximum length of arc that can be maintained, can be found in terms of the generator E. M. F. and the current.

Regarding the distribution of energy in the arc, it has long been known that the principal drop of voltage in an arc occurs between the positive electrode and the arc. By reference to Table 5 it is observed that the voltage drop between the positive carbon and the arc increases as the length of the arc increases. Referring to Table 6 it is observed that the voltage drop between the negative carbon and the arc does not vary with the length of the arc, but diminishes as the

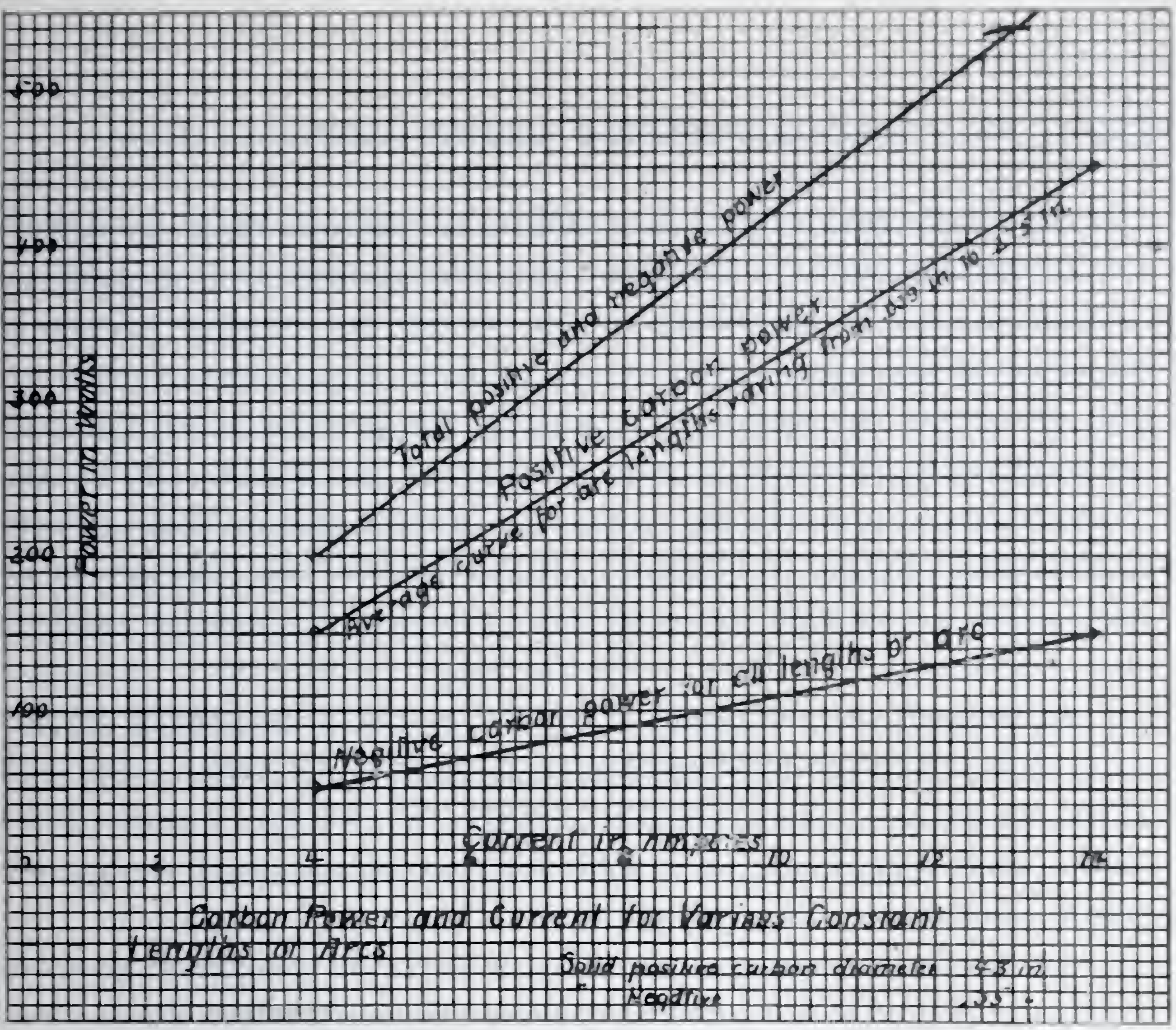
Total positive and negative power
Positive Carbon power
Average curve for arc lengths varying from .039 in to .275 in
Negative carbon power for all lengths of arc
Power in Watts
Current in Amperes
Carbon Power and Current for Various Constant Lengths of Arcs
Solid positive carbon diameter .43 in.
Negative .55

Fig. 19

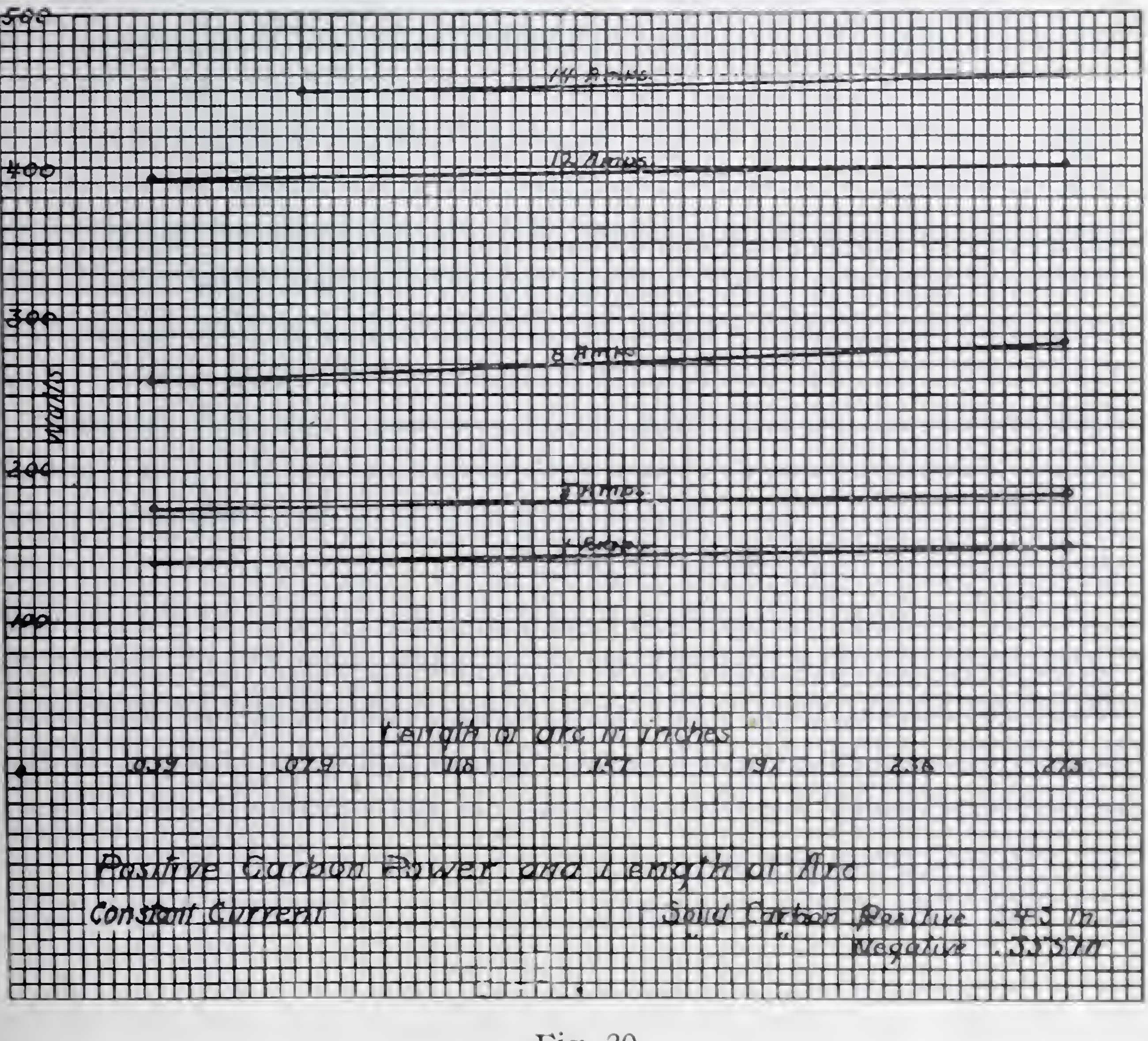
14 Amps.
12 Amps.
8 Amps.
Watts
Length of arc in inches
Positive Carbon Power and Length of Arc
Constant Current
Solid Carbon Positive .43 in.
Negative .55 in

Fig. 20

current increases. From the results of various tests by different experimentors, it is seen that the proportion of positive carbon energy to the total energy in the arc is approximately 80 per cent for any length of arc and for any value of current. Fig. 19 shows the value of energy in the positive and negative carbons with different values of current, as it also shows the proportions of positive and negative carbon energy respectively to the total energy in the arc. Reference to Fig. 20 will show that with a constant current, the amount of positive carbon power changes very little with the length of the arc.

Inasmuch as the quality of the positive electrode varies with different materials which it is desired to weld, and it is impracticable to maintain the length of the arc within close limits, it is necessary to select a value of external resistance which will meet the worst conditions.

In the Bernardos process, the material it is desired to weld is always the positive terminal of the arc; and since the largest proportion of the energy in the arc (and consequently the greatest heat) is dissipated at the contact between the positive terminal and the arc, it is apparent that this characteristic distribution of energy adds very materially to the efficiency with which the operation is performed. In this connection it might be well to mention that a direct current arc is better adapted for welding purposes than an alternating current arc. If an alternating current arc were used, approximately 80 per cent of the energy would be dissipated alternately on the metal and on the carbon electrode, which would result in a dissipation of heat on the carbon where it is not desired; a rapid consumption of the carbon and a transfer of carbon particles, during the one-half wave when the carbon is positive, from the carbon to the metal.

The ratio of the energy expended in the arc to the energy developed by the generator is a very important factor in determining the most efficient arrangement to use in maintaining an arc. The ratio of the power expended in an arc to the power developed by the generator is greater—

1° The shorter the arc;

2° The larger the current;

3° The more nearly the external resistance and the E. M. F. of the generator approach to the minimum with which the arc can be maintained.

The influence on this ratio of the first is negligible, and assuming that the current is fixed, the ratio of energy in the arc to the energy developed by the generator is greater the shorter the arc, the smaller the external resistance and E. M. F. of the generator. The smallest external resistance that can be used with any current varies inversely as the square of the current.

It has been stated that it is necessary to maintain an arc length of not less than approximately two inches. We have shown that the ratio of positive carbon energy to the total arc energy is approximately the same for any value of current. It is, of course, desirable to keep as high as possible the ratio of energy expended in the arc to the energy delivered by the generator. With a fixed minimum arc length of two inches, and an energy depending on the particular operation, it seems that it is desirable to use a large current in order to reduce the external resistance required, as well as to reduce the voltage of the generator.

The external resistance can consist of iron grids, water rheostat and many other forms, or the characteristics of the generator can be such as will furnish the necessary steadying resistance for the arc. This means that a direct current generator with a sufficiently bad voltage regulation, theoretically, is adapted for welding purposes.

In the Zerener process of arc welding, it will be noted that the material to be heated is not one of the electrodes of the arc. The arc flame is directed against the material with a blow pipe, or magnet. It has been shown that in an electric carbon arc a very small per cent of energy appears in the flame. It is apparent, therefore, that this method of heating materials is extremely inefficient.

There are a great many cases where it is necessary to apply heat, to which the electric arc is particularly adapted, and there is little doubt but that future applications will be very greatly extended.

I might add that a couple of years ago, in connection with the plant of the National Tube Works, at Lorain, Ohio, there were four old bridges that they wanted to remove, and the cheapest way was to use the electric arc to cut them. It has been used in a great many cases for removing structural material in the last few years.

MR. F. W. STEVENS: We have had steel rolls of 95 or 100 carbon in which it was necessary to weld up holes in the the ends to provide solid material in which to drill for lathe centers. After welding with the arc we found the rolls so hard at this point that we were unable to drill them, breaking the ends of drills in the attempt. We concluded that the steel, being of such high carbon, had air hardened in cooling after welding. I am sure that the connections were properly made, for I have reversed them at different times with the result, that with reversed connections we were unable to weld at all, as we were unable to maintain an arc. I wish to inquire whether high carbon steel is more likely to exhibit this resistance to machining, by extreme hardness after welding, than a low carbon steel.

THE AUTHOR: I have not met with the experience you mention.

MR. U. W. TINKER: We are making commercial use of the arc in a steel casting plant very successfully. We have a very experienced man, having found that the best is the cheapest in the long run, and have gone so far in developing the use of the arc as to put teeth in a gear where the teeth have been entirely broken out. Our practice with shrinkage cracks is to cut the crack out entirely, making an opening of appreciable size, which is filled up starting to build in around the edges. We repair large spindles for rolling mills when the corners on the coupling end have worn by welding on new corners. There are many uses to which the arc can be put around a steel foundry.

THE AUTHOR: I would like to know if anybody has obtained better results with a flux different from the one

mentioned in the paper. After analyzing a number of fluxes, and giving each a thorough trial, we have finally selected as the best a mixture of red oxide of iron (15 to 25 per cent), and borax (85 to 75 per cent); if red oxide is not available, the black oxide may be used, though it is not quite so good and is more expensive.

Mr. C. Pirtle: We have used the same flux, red oxide and borax, but as far as possible we try to avoid the use of any flux, and we find that it is possible to do that in probably the great majority of cases by using a soft Swedish iron for the filler and using an arc of proper length, not too short, that is over 2 in. and less than 4 in., and not forcing the arc at the carbon to too high a density. If 800 or 1000 amperes are used, a 2 in. or 2½ in. carbon should be employed instead of 1 in. or 1½ in. carbons. Why that is I do not know, but possibly under the stress of the high current density the carbon is removed mechanically and gets into the weld. In large welds a considerable percentage of soft steel punchings may be used, and in fact in filling large blow holes with Swedish iron entirely, the center of the mended area does not seem to have changed in character sufficiently to make it a steel in any sense of the word, whereas in the smaller weld it appears to take up a sufficient amount of carbon to make it a mild steel.

Mr. L. R. Palmer: I would like to ask Mr. Tinker about the wobblers on rolls, whether any special effort was made to make the wearing surfaces hard? There are some cases where we do not care about machining, but would like to have the faces hard. Can you successfully harden the surfaces by reversing the polarity and making the carbon the positive and finishing the wearing surface in that way? Of course, where there is considerable metal to fill in it would take too long to work it throughout on the positive carbon, but it would seem possible that it might be finished with the positive carbon, thereby giving a very hard wearing surface that did not require machining. Have you used any such method?

Mr. U. W. Tinker: We have simply put square corners on the wobble head without special regard as to hardness.

Mr. L. R. Palmer: I know of cases where that has been done, and the men in the mill claimed that they were too soft and did not stand up under the load. Which is the better process to use for this work, the electric arc or Thermit?

Mr. U. W. Tinker: If the work is large, cast the lugs and then weld them on the casting. The same method can be used for spindles. Our experience with the Thermit has not been good.

Mr. H. A. Steen: The Birkeland-Eyde process for separating hydrogen from air employs a rotating electric arc, appearing as a flaming disc. The rapid rotation of the arc is obtained by a rotating magnetic field. The field is produced by a set of magnet poles, the polarity of which is constantly changing. It occurs to me that this method could be employed for welding, the spreading arc would cover a considerable surface and quicker and more uniform welding would be possible. The design of such a welder might, however, involve complications.

Mr. Richard Hirsch: There should be a number of advantages in welded seams in tanks, if, as I understand is the case, the weld is near 100 per cent efficiency. What would be the comparative cost between an electrically welded and a riveted joint, taking into consideration the strength secured with a little less material?

The Author: Not having had any experience with electrically welded tanks, I am not prepared to give figures as to relative costs. I never would, however, recommend arc welding for tank work. It is impossible to regulate the arc properly, and, in consequence, a hole may be burned through the tank at any moment. The best way to weld a tank, it seems to me, is either by the Thomson or resistance method, which was very fully explained in a recent number of the American Machinist;* or, if the tank is of very thin material, the oxy-acetylene process will prove preferable.

I would like to say further if Mr. Pirtle has a method of welding cast or malleable iron while cold, he is to be congratu-

* American Machinist, February 25, 1909.

lated. At the present time, as far as I know, there is no way of making such a weld without preheating.

MR. C. PIRTLE: The pieces on the table were welded that way.

THE AUTHOR: The samples of welds submitted are very good. Castings of a compact shape may occasionally be successfully welded while cold, but such are only the exceptions which prove the rule.

MR. C. PIRTLE: We have not carried that far enough to make any definite statement. We have not tried to weld anything as thin as stove castings, though we have filled a ½ in. hole in the end of a cast iron grid.

MR. A. STUCKI: Regarding Mr. Hirsch's question as to the relative cost of welding and riveting, I may say that recently we carefully compared riveting with oxy-acetylene welding. The metal was about ⅛ in. thick and the joint had to be strong, but not tight. The riveting proved to be by far the cheaper of the two.

This process reminded me more of soldering than of welding, as a strip of steel was fused to make the joint in addition to the two sheets, which lapped each other. This joint was at least as strong as the original sheet.

In the case of Thermit welding, the conditions are entirely different. Here we simply fuse the Thermit to form a bond between the two abutting but slightly separated surfaces, and the strength depends on one thing on the thermit itself, then on its bond, and finally on the structure left in the material of the two abutting sheets. This is undoubtedly greatly changed, inasmuch as the layers nearest the weld are heated to fusion, while other layers near by are left relatively cold.

In brazing the conditions are better. Here we heat the parts which are to be united, thoroughly and uniformly, so that the internal strains cannot be so great, even if the structure of the metal should be changed and weakened.

Coming back to the electric welding, I have listened with interest to the paper and the discussion, and have especially

noted what has been said about cutting out shrinkage cracks; but how about the internal strains set up by such a procedure? These must be very great, and it is a question whether they can be entirely eliminated by subsequent annealig, and in view of this and of the preceding remarks, I would like to ask the gentlemen whether the electric unison is considered and recognized as a thorough weld or whether it is used only in temporary work or in cases where maximum strength is not required.

Mr. E. K. Hiles: I understand that transformer tanks are now being welded. Which process is used in this work?

Mr. F. W. Cox: We have used, to a limited extent, self-cooled transformer tanks, made of 1/4 in. boiler plate, all joints in which were welded by the oxy-acetylene process.

Mr. Richard Hirsch: What is the strength of such welds in proportion to that of the solid plate?

Mr. F. W. Cox: While we have no definite information as to the strength of welds made by the oxy-acetylene process, the fact that this process is used to a considerable extent in the repair of marine boilers is sufficient proof that such welds will be amply strong for the ordinary run of work.

(Many of the illustrations in this article were furnished by the American Machinist and the Electric Journal, whose courtesy we wish to acknowledge.—Editor.)

THE STEEL OIL DERRICK

By R. B. Woodworth.*

The magnitude of the oil and gas industry in the United States is reflected in the statistics of production as well as in the legislation which has been directed by state and general governments against its chief benefactor. Once the occupation of speculators engaged in the hazardous pursuits of most uncertain treasure with reckless disregard of law and order it has become a sober business in which, if hazard has not been and cannot altogether be eliminated, capital combined with sound business methods and technical experience cannot fail to reap sure and large rewards. Sound business methods as applied to production mean the use of modern materials of construction fitted for long endurance and repeated service; tools rather than temporary devices; machines rather than structures; and the most productive wells for the least ultimate expenditure in equipment.

The petroleum industry in the United States originated in the Great Kanawha Valley at the Salt or Buffalo Lick, near Charleston, W. Va., where David and Joseph Ruffner drilled a hole into the salt sand with a 2½ in. chisel bit of steel attached by a rope to a spring pole and were rewarded on January 15th, 1808, by an ample flow of brine for their salt furnace. This well was cased with two long strips of wood whittled into half tubes wrapped with twine. In 1831 William Morris invented that portion of a string of tools called the "jars," which with the adoption of the heavy sinker and other minor improvements gave great impetus to deep well drilling in the Kanawha Valley, so that previous to 1876 wells 2000 ft. deep had been completed and would probably have been carried farther had people not wanted salt instead of oil.

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* Engineer with the Carnegie Steel Company.

In 1841 William Tompkins struck gas in a salt well which he used for boiling his salt furnace. All of the salt wells contained oil in larger or smaller quantities and the early settlers also washed oil out, collected it in cloths from the river and sold it in Parkersburg, Marietta, Cincinnati, etc. One of these operators was George S. Lemon, of Hughes River, W. Va., who rigged up an arrangement for drilling by water power and in 1844 drilled a hole over 100 ft. deep, struck oil, saltwater and gas and sold the oil with that from the river sands. Oil from this well was sold down to 1860 at prices from 33 to 40 cents per gallon. The records from the Kanawha and from the Muskingum districts prove conclusively that a large commercial business in petroleum was already in existence in West Virginia and Ohio both from drilled wells and sand pits long before the first well was completed at Titusville. The first well drilled in West Virginia solely for petroleum was put down on Burning Springs Run with a spring pole in 1859 and completed May 1st, 1860, when at 303 ft. oil was struck in the Dunkard Sand. A second well came in late in 1860, and these two wells brought the West Virginia oil territory into great prominence and development which was stopped in 1863 by General Jones with 3000 Confederate cavalrymen who destroyed the accumulated oil, estimated at 300 000 barrels, and frightened away the Northern capitalists who had invested their money in the Burning Springs Field. The burned wells became water-logged and the region has never recovered from the conflagration.*

The oil found in the salt wells was considered a nuisance until its advantageous application in the arts and sciences was made the subject of scientific investigation. Previous to 1853, therefore, petroleum was used mainly in medicine and sold as a liniment, the bottles being often embellished with a picture of the well and the derrick standing over it. In 1851 when crude oil was worth 75 cents a gallon at Oil Creek it was tested as a crude material for illuminating purposes by William and Luther Atwood and Joshua Merrill at the United States Chemical Manufacturing Company's Works at Waltham,

* West Virginia Geological Survey, Morgantown, W. Va., Vol. 1-A, 1904.

Mass., and its merits fully established. In 1853 Dr. Brewer suggested its use for illumination and lubrication and set to work to devise means for refining. In 1855 refined petroleum was freely offered for sale in Pittsburgh, but the quantity was too small to influence even the local trade though it did stimulate to some extent the market for crude. About 1858 some oil from one of the natural springs near Titusville was sent to Professor B. Silliman, Jr., of Yale College, whose report on its merits was so satisfactory that a company was organized in New Haven and E. L. Drake sent to Titusville to drill a well. He encountered great difficulties in the movement of his machinery but finally began drilling on Oil Creek. Here he encountered quicksand and had difficulty in keeping water out of his well. He, therefore, drove an iron pipe 36 ft. down to rock to prevent the inflow of water and sand. This device is said to have been original with Drake, and the demonstration of the possibility of shutting out quicksand and especially salt water by the use of casing marks an era in the development of the art of drilling. After drilling 33 ft. into the rock the drill fell 6 in. into a crevice on August 28th, 1859, and operations were suspended for the day. The next morning the drill hole was found nearly filled with petroleum and a new industry had been inaugurated. No point in the entire region could have been located where the oil was to be obtained nearer the surface than the exact spot where Colonel Drake began to drill.

From Oil City the production of petroleum extended to all parts of the United States and is a matter of history into which there is no need at present to enter. A few notes as to the other fields than those of Pennsylvania may be of interest. Attempts to drill wells were made in different counties in West Virginia but without success because operators had not yet learned how to deal successfully with rocks that crumble or cave and fall into the hole when water touches them. West Virginia waited 30 years for improvements in the art of drilling though many of the old wells which were started and abandoned were over pools of great richness. In 1889 the Eureka and Mannington Pools were opened and West Vir-

ginia became a great producing state, reaching its maximum production in 1900.

In the Lima-Indiana Field oil was first produced at Findlay, Ohio, in November, 1885, from the Trenton Limestone of the Lower Silurian or Ordovician Period. The production in Ohio reached its height in 1896.

Crude oil was first discovered in the Corniferous Limestone of Indiana in the city of Terre Haute in 1865 by Chauncy Rose, who started boring in search of water and struck oil at 1629 ft. Petroleum in commercial quantities was first produced in Indiana, however, in 1889, from the Trenton Limestone in a well put down by the Northern Indiana Oil Company near Keystone, Wells County.

One or two wells yielding marsh gas are said by W. S. Blatchley* to have been drilled near Champaign, Ill., in 1853. Wells were put down for oil at Oilfield in 1865 and near Litchfield in 1882. Those wells were not cased and in consequence were drowned out by saltwater. Some of these wells began to yield oil in 1889 and continued in small quantities until 1903, when the production ceased, but the total production in fourteen years was only 6576 barrels. A well which had an initial production of 35 barrels per day was completed near Oilfield, Clark County, Ill., on October 20th, 1904, and started the production of the Casey Field.

Oil was first produced in the Mid-Continent Field (Missouri, Kansas and Oklahoma) in 1899 by the drilling of a well near Chanute, Kan.

The Gulf Coastal Oil Field, including Texas and Louisiana, was first opened for production in commercial quantities by the discovery of oil in 1901 at Beaumont, Texas. This field was characterized by gushing wells of high initial volume but of short duration. Texas made its maximum production in 1905 and Louisiana in 1906.

California produced petroleum in small quantities between 1865 and 1892. In the latter year a well was drilled in the city of Los Angeles which inaugurated the real development of that territory, the output of which has been increasing continuously since that date.

* Illinois Geological Survey, Bulletin No. 2.

Oil is produced in England by the distillation of the shale rock in which it is contained. This method of production was first undertaken in France in 1834 and was introduced into Scotland in 1850.

In a general way the commercial supremacy of the United States is due to the exploitation of its natural resources and the first place has to be given to the farmer and agricultural products. The relative importance of the production of oil and gas as compared with other products won from the soil by mining methods is shown in Table 1, re-arranged from *Mineral Resources of the United States for* 1907, issued by the United States Geological Survey. This table gives the values in dollars of the fourteen chief products of our mines and quarries and is of interest to engineers as giving also at the same time a graphic conspectus of the development of modern materials of construction in buildings and bridges. It will be noted that the increase in the production of cement has been accompanied by a decrease in the production of lime, and that clay products such as brick and terra-cotta have come to the front at the expense of building stone.

So far as petroleum is concerned it may be said that while this table gives relative values, a true estimate of the increase in production cannot be based on values in dollars and cents. In December of the year 1859 the price of crude oil was $20.00 a barrel; in December 1861 ten cents a barrel. The price varies with the character of the oil and its distance from the market. In 1907 the average prices at the wells per barrel of 42 gallons were as follows:—

New York	$1.755
Pennsylvania	1.758
West Virginia	1.743
South Eastern Ohio	1.743
Kentucky and Tennessee	1.05
North Western Ohio	.90
Indiana	.88
Illinois	.68
Kansas	.28
Oklahoma	.28
Texas	.84
Louisiana	.79
California	.37

	1880		1890		1900		1905		1906		1907	
	Value in Dollars	%	Value in Dollars	%	Value in Dollars	%	Value in Dollars	%	Value in Dollars	%	Value in Dollars	%
TOTAL	364,928,298	100	606,476,380	100	1,107,031,392	100	1,625,135,835	100	1,904,007,034	100	2,069,289,196	100
Pig Iron	89,315,569	24.5	151,200,410	24.9	259,944,000	23.5	382,450,000	23.5	505,700,000	26.6	529,958,000	25.6
Copper	11,491,200	3.1	30,848,797	5.1	98,494,039	8.9	139,795,716	8.6	177,595,888	9.3	173,799,300	8.4
Gold	36,000,000	9.9	32,845,000	5.4	79,171,000	7.2	88,180,700	5.4	94,373,800	5.0	90,435,700	4.4
Lead	9,782,500	2.7	12,668,166	2.1	23,561,688	2.1	28,690,000	1.8	39,917,442	2.1	38,707,596	1.9
Silver	34,717,000	9.5	57,242,100	9.4	35,741,100	3.2	34,221,976	2.1	38,256,400	2.0	37,299,700	1.8
Zinc	2,277,432	0.6	6,266,407	1.0	10,654,196	1.0	24,054,182	1.5	24,362,668	1.3	26,401,910	1.3
Coal	95,640,396	26.2	176,804,573	29.2	306,688,164	27.7	476,537,294	29.3	513,079,809	27.0	614,798,898	29.7
Petroleum	24,183,233	6.6	35,365,105	5.8	75,989,313	6.9	84,157,399	5.2	92,444,735	4.9	120,106,749	5.8
Natural Gas	......	......	18,792,725	3.1	23,698,674	2.1	41,562,855	2.6	46,873,932	2.5	52,866,835	2.6
Clay Products	200,457	0.1	9,256,000	1.5	96,212,345	8.7	149,697,188	9.2	161,032,722	8.5	158,942,369	7.7
Building Stone	18,356,055	5.0	47,000,000	7.8	36,970,777	3.3	63,798,748	3.9	66,378,794	3.5	71,105,805	3.4
Cement	1,852,707	0.5	6,000,000	1.0	13,283,581	1.2	35,931,533	2.2	55,302,277	2.9	55,903,851	2.7
Sand and Gravel	......	......	......	......	......	......	10,115,915	0.6	11,489,420	0.6	13,242,002	0.6
Lime	19,000,000	5.2	......	......	6,797,496	0.6	10,941,680	0.7	12,480,653	0.7	12,640,512	0.6

TABLE No. 1.

METALLIC AND NON-METALLIC MINERAL PRODUCTS OF THE UNITED STATES OF AMERICA.

Apart from the location of the wells and convenience of access to the markets this table indicates in a very clear way the superiority of the oils from the Appalachian Field and the low character of the oils from Kansas and Oklahoma. There are five great divisions into which the oil fields of the United States are divided for statistical purposes, and these divisions correspond quite closely with the matter of chemical purity and ease of refinement. The distinction between grades of oil is based primarily on the percentage of sulphur which determines whether or not the oil requires special treatment to eliminate this element. A second criterion is the proportion of asphalt and paraffin wax obtainable from the crude oil. Briefly described these fields are as follows:

Appalachian Field. Including Western New York, Pennsylvania, South Eastern Ohio, West Virginia, Kentucky and Tennessee. The oils in this field are practically free from sulphur and asphalt, are rich in paraffin wax, and yield the largest percentage of gasoline and illuminating oil.

Lima-Indiana Field. Including North Western Ohio and a strip in the middle of Indiana. This field yields oil with sufficient sulphur to require special treatment for its elimination and like the Appalachian oil it yields paraffin wax.

Illinois Field. The oil of the Illinois Field contains less sulphur than the Lima-Indiana and much of it can be refined without special treatment. On the other hand some of it contains asphalt as well as paraffin. This oil comes chiefly from the Casey Territory in Clark County.

Mid-Continent Field. This includes South Eastern Kansas, Oklahoma and Missouri, and the oils contain both asphalt and paraffin, and are heavy in character. They are used principally for fuel oil and lubricating purposes.

Gulf Field. This field includes all oils in Texas and Louisiana. Near the Gulf they contain considerable quantities of sulphur, much of it in the form of sulphureted hydrogen. Their location makes them well suited for fuel oil, especially for export. The oils of Northern Texas, principally from Corsicana, are lighter and contain less sulphur.

California Field. California oils are generally characterized

by much asphalt and little or no paraffin; the lighter grade comes from the Santa Maria district.

Table 2 shows very clearly the present position of petroleum production in the United States, and indicates in a general way the reason why the oil of the Appalachian Field stands higher in price than that of the newer developments. The Appalachian Field is on its decline. The output of Pennsylvania and New York has given place to West Virginia and Ohio, while the enormous production of recent years has come from the newer fields in Texas and California where the oil is of poorer quality and the difficulties of refining are larger. It also shows why we may expect the price of refined oil for illuminating purposes and of gasoline for automobile consumption to increase continuously. It also indicates the importance of the warnings given the dwellers in the Appalachian District, and especially to the City of Pittsburgh, to conserve its fuel supply lest its supremacy in the manufacture of iron and steel depart to other more favored localities. It will be noted that the production of Pennsylvania has varied but little in the last three or four years, and as a matter of interest in the general subject under discussion it may be well to set down the number of wells from which the oil and gas shown in these statistics are produced. The number of oil wells December 31st, 1906, in the entire United States is not known. There were, however, in the Lima-Indiana Field 35 953; in Illinois 2810; in California 2916. During 1907 there were drilled for the production of petroleum 19 601 wells, of which 15 526 produced oil, 450 gas, and 3625 came out dry. There were 5064 wells abandoned that year, making a net gain of 10 912 wells.

On December 31st, 1906, there were 17 226 wells producing gas. In 1907, 3164 wells were drilled, of which 2484 were productive, 680 were dry, and 1036 were abandoned; making the net gain for the year in productive wells 1448.

The total number of wells drilled in 1907 for oil and gas was 22 765, and if we add to this number salt wells, artesian wells and other bores of great depth it will be seen that the exploitation of the manufacture and sale of steel oil derricks has before it a field of large promise. This field is one into which

	1860		1865		1870		1875		1880		1885		1890		1895	
	Barrels	%	Barrels	%	Barrels	%	Barrels	%	Barrels	%	Barrels	%	Barrels	%	Barrels	%
TOTAL	500,000	100	2,497,700	100	5,26[illegible],745	100	8,787,514	100	26,286,123	100	21,858,785	100	15,823,572	100	52,892,276	100
New York & Penna.	500,000	100	2,497,700	100	5,260,745	100	8,787,514	100	26,027,631	99	20,776,041	95.5	28,158,208	62.3	19,144,390	36.2
Ohio									38,940	.1	661,580	3.0	16,124,656	35.2	19,545,233	37 0
West Virginia									179,000	.7	9 000	.4	492,578	1.1	8,120,125	15,4
Kentucky & Tenn.											5 64		6,000		1,500	
Indiana													63,496	.1	4,386,132	8.3
Illinois													900		200	
Okla.-Kans.-Mo.													1,478		44,477	.1
Texas													54		50	
Louisiana																
Colorado													368,842	.8	438,232	.8
Wyoming															3,455	
California									40,552	.2	325,[illegible]00	1.5	307,360	.7	1,208,482	2.3

	1900		1901		1902		1903		1904		1905		1906		1907	
	Barrels	%	Barrels	%	Barrels	%	Barrels	%	Barrels	%	Barrels	%	Barrels	%	Barrels	%
TOTAL	63,620,529	100	69,389,194	100	88,766,916	100	100,461,337	100	117,080,960	100	134,717,580	100	126,493,936	100	166,095,335	100
New York & Penna.	14,559,127	22.9	13,831,996	19.9	13,183,610	14 9	12,518,134	12.5	12,239,026	10.5	11,554,777	8.6	11,500,410	9.1	11,211,606	6.8
Ohio	22,362,730	35.2	21,648,083	31.2	21,014,231	23.7	20,480,286	20.4	18,876,631	16.1	16,346,660	12.1	14,787,763	11.7	12,207,448	7.4
West Virginia	16,195,675	25.5	14,177,126	20.4	13,513,345	15.2	12,899,395	12.8	12,644,686	10.8	11,578,110	8.6	10,120,935	8.0	9,095,296	5.5
Kentucky & Tenn.	62,259	.1	137,259	.2	185,331	.2	554,286	.6	998,284	.9	1,217,337	.9	1,213,548	1.0	820,844	.5
Indiana	4,874,392	7.7	5,757,086	8.3	7,480,896	8.4	9,186,411		11,339,124	9.7	10,964,247	8.1	7,673,477	6.1	5,128,037	3.1
Illinois	200		250		200						181,084	.1	4,397,050	3.5	24,281,973	14.6
Okla.-Kans.-Mo.	82,788	.1	191,486	.3	369,606	.4	1,074,125	1.1	5,620,099	4.8	12,016,595	8.9	21,722,148	17.2	45,937,649	27.7
Texas	836,039	1.3	4,393,658	6.3	18,083,658	20.4	17,955,572	17.9	22,241,413	19.0	28,136,189	20.9	12,567,897	9.9	12,322,696	7.4
Louisiana					548,617	.6	917,771	.9	2,958,958	2.5	8,910,416	6.6	9,077,528	7.2	5,000,221	3,0
Colorado	317,385	.5	460,520	.7	396,901	.4	483,925	.5	501,763	.4	376,238	.3	327,582	.3	331,851	.2
Wyoming	5,450		5,400		6,253		8,960		11,542		8,454		7,000		9,339	
California	4,324,484	6.8	8,786,330	12.7	13,984,268	15.8	24,382,472	24.3	29,649,434	25.3	33,427,473	24.8	33,098,598	26.2	39,748,375	23.9

TABLE No. 2.

PRODUCTION OF PETROLEUM IN BARRELS OF 42 GALLONS IN THE UNITED STATES OF AMERICA.

incursions have been made in recent years though without much success chiefly for the reason that those who made the incursions either did not understand the conditions to be met and the needs and prejudices of the operators or were not willing to meet them.

GEOLOGICAL CONDITIONS AFFECTING THE DEPTH OF WELLS

The question "How deep is an oil well?" may appear to men engaged in designing and detailing structural steel work as parallel with the question "How long is a bolt?" and like that famous question the correct answer can only be made when we know the thickness of the material through which the well has to go. To determine this is the province of the geologist, and just as it is important, nay rather necessary, that a mining engineer should understand and utilize the principles of geologic science affecting the distribution and production of coal, so is it important that those whose province it will be in the future to meet the needs of the drillers in the way of drilling mechanism and equipment should acquaint themselves at least with the elementary facts which determine the distribution of oil and gas throughout our territory and the character of the strata which must be penetrated by the drill to win therefrom the hidden treasures below the earth's surface.

The early shallow oil wells were located from surface indications in the way of oil scum, burning springs, etc., but in the ultimate analysis the fields were discovered by accident. The scientific exploitation of our oil and gas resources is due to the investigations of Dr. Edward Orton, Jr., late State Geologist of Ohio, and of Dr. I. C. White, State Geologist of West Virginia, whose researches were undertaken at the instance of J. J. Vandergrift, at that time President of the Forest Oil Company of Pittsburgh, and since June, 1883, the drill has but verified the truth of geological conclusions. One of the earliest instances of the application of geological science to the discovery of oil wells is that of the Mount Morris-Mannington Field, an account of which is given by the discoverer, Dr. White, in the *West Virginia Geological Survey, Vol.*

1-*A*, *p.* 54. Another example is the case of the Gaines Oil Field in Tioga County, Pa., where the first dry well was drilled in 1884 by C. F. Billings. A number of attempts to produce oil were made in this field but without success for the reason that the Gaines Pool is only a few hundred feet in width and consequently hard to discover. It was discovered by the use of scientific knowledge in 1898, when E. M. Atwell drilled a productive well near Galeton, east of Watrous, in what, from its discoverer, has been called the Atwell Sand.

Oil is derived from the slow destructive distillation of plant and animal remains found in shale, limestone or sand rock, and gas is derived from the volatilization of the oil, the residuum of this volatilization being asphalt such as is found, for instance, at Lake Trinidad, which was originally supposed to be the crater of an extinct volcano. According to geological theory four conditions are necessary for the accumulation of oil or gas in commercial quantities:

1° A porous stratum to form a reservoir. In sandstone this occurs where the sand is of a conglomerate character having large or small grains separated by larger or smaller interstices. In the limestones the necessary porosity of structure is due to chemical change in the limestone itself by reason of which carbonate of lime is changed to dolomite with a shrinkage in the size of the crystals.

2° An imperative rock cap above the reservoir to prevent the escape of the oil or gas contained therein.

3° An arched or anticlinal structure of the rock in which the reservoir is located. As a corollary to this proposition it has been demonstrated that it is useless to drill for oil or gas in a level country, there being no condition under which the action of gravity could compel the gas, oil and saltwater to arrange themselves in quantities according to their specific gravity. Contrariwise it has been demonstrated that where the anticlinal slope is more than ten degrees the strata becomes so broken as to prevent the accumulation of either oil or gas which escape by volatilization into the atmosphere through the crevices caused by the tectonic forces responsible for the upheaval of mountains and highlands.

4° A pressure behind the oil or gas to force it into the reservoir. This pressure is known by the drillers as the "rock pressure," and is usually hydrostatic; that is to say, it is roughly speaking equivalent to the weight of a column of water reaching from the oil or gas bearing sands up to the surface; though this condition is not always observed. One of the practical things in connection with the rock pressure, which of course changes from depth to depth of strata, is the possibility to draw the gas or oil from one stratum or rock and to store it in a porous stratum nearer the surface which of itself may not contain either oil or gas. This method of underground storage has been prosecuted with intelligence and complete success.

Under geological principles the saltwater usually associated with the presence of oil or gas flows down the slopes taken by the strata as a result of tectonic forces through the porous sand or limestone, forcing the oil and the gas ahead of it. Under the action of gravity the saltwater settles in the hollows of the strata known by the geologists as synclines while the oil finds its place up the slope of the anticline and the gas settles at the very top.

Fig. 1 is a contour map of the Burgettstown quadrangle just west of McDonald re-drawn from *Bulletin* 318 *of the United States Geological Survey*, and indicates the occurrence of oil and gas in this field. Contours are given at an interval of 50 ft. and show the level of the top of what is known by the drillers as the Hundred Foot Sand. In order to avoid minus quantities the elevations are given as above an assumed plane of 2000 feet below mean sea level. The oil wells in Pool *A* are in the Gordon, Fourth or Fifth Sands; in Pools *B* and *C* in the Hundred Foot. The gas wells are found in all sands but for the purpose of this paper their location with reference to the oil is the only item of interest. It will be noted that they occur in the higher portions of the field.

The data on which maps of this character are based are the records of the drilling of the wells furnished chiefly by the oil and gas companies. The drillers make mistakes in their identification of the sands through which the wells are drilled,

but where the records are complete the necessary allowances may be made and correct conclusions derived therefrom as to the approximate depth at which any particular stratum might be reached and the service of geology in the production of oil and gas consists in the accurate delimitation of the boundaries

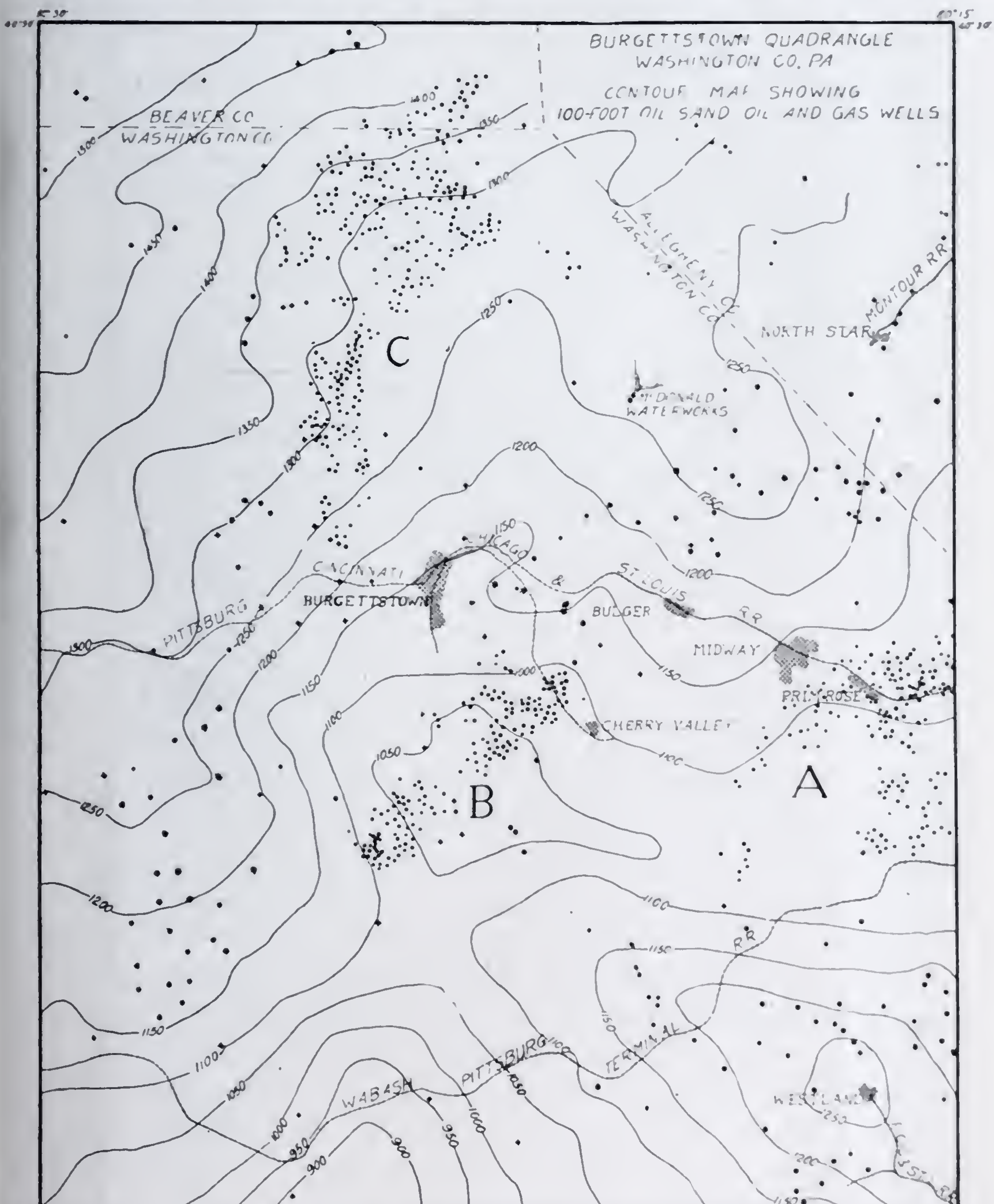

Fig. 1. Contour Map Burgettstown Quadrangle, Washington County, Pa.

of the oil and gas territories; and while it is not possible at all times to take a geological map and to drive a well guaranteed to be productive, yet the utilization of the services of this branch of science has beyond question prevented in large measure that wasteful expenditure which arises from drilling for oil or gas in localities where their presence is absolutely contrary to geological facts as to their occurrence. It is beyond the powers of geological science to foretell whether any particular boring will yield either oil or gas in commercial quantities, but it does limit the search to regions having a peculiar geological structure where experience has shown that the occurrence of oil and gas is probable.

The series of rocks in which oil and gas are found are all sedimentary; that is to say, they have been deposited in place as the result of the erosion of previously existing earth surfaces. They have been given names by geologists which differ in different localities. They have also been described with different names by the drillers which are usually derived from the place where the first oil or gas was found in the particular strata. The Bayard Sand, for example, is named from Thomas Bayard, on whose farm about four miles southeast from Waynesburg, Pa., a very large gas well was obtained in it by the Carnegie Natural Gas Company; the Atwell Sand in like manner was named from E. M. Atwell, who first drilled a productive well into it. Inasmuch as it is impossible to have an intelligent appreciation of the distribution of oil and gas and the literature of its production without a knowledge of the nomenclature of the oil and gas producing strata, it may be well to set down here a table, Fig. 2, showing the correlation between geological names and drillers' designations. This table has been prepared from various publications and checked by the geological folios of the *United States Geological Survey*, and while it may not be absolutely correct as to detail, it is presented as a guide to the understanding of the subject. It must be said in this connection, however, that all these strata do not occur in all localities. Fig. 3, taken from *Bulletin No.* 318 *of the United States Geological Survey*, shows a cross section through Pennsylvania and West Virginia indicating the posi-

Age	Period	Series	Formation	Symbol	Distance to Pittsburgh Coal	Geologic Name of Member	Drillers' Names	Other Designation	Where Productive
Cenozoic	Quart'ry	Pleistocene	Recent		6500				
			Champlain						
			Glacial						
	Tertiary	Pliocene Miocene Eocene	Chipola						Tex., La.
			Vicksburg						
			Jackson						
			Claiborne						
			Chickasaw						
			Midway						
	Cretaceous		Laramie	Kl	5400				
			Fox Hills	Kfs	5600				
			Pierre	Kp	5100				
			[illegible]	[illegible]	[illegible]				
	Jurassic		[illegible]	[illegible]	[illegible]				
	Triassic		Spearfish	Trs	2000				
Palaeozoic	Carboniferous	Dunkard	Greene	Cg	1130	Windy Gap Limestone			
						Gilmore Sandstone			
						Ninevah Sandstone			
						Ninevah Coal			
						Ninevah Limestone			
						Dunkard Coal			
						Ten Mile Coal			
			Washington	Cw	680	Upper Wash'n Limestone			
						Middle Wash'n Limestone			
						Lower Wash'n Limestone			
					390	Waynesburg Sandstone	Bluff Sand		
		Pennsylvanian	Monongahela	Cm	330	Waynesburg Coal	Waynesburg Coal	Pinhook Coal	
						Uniontown Coal			
						Benwood Limestone			
					110	Sewickley Coal (Redstone)	Mapletown Coal		
					100	Pittsburg Coal	Pittsburg Coal		West Va.
			Conemaugh	Cem	40	Connellsville Sandstone			
					200	Morgantown Sandstone	Murphy Sand		W Va.
						Ames(Crinoidal)Limestone			W Va
					370	Saltsburg Sandstone	Little Dunkard Sand	First Cow Run Sand	S E. O.
					500	Mahoning Sandstone	Big Dunkard Sand	Hurry Up Sand	S W. Pa., W. Va
			Allegheny	Ca	600	Upper Freeport Coal	Connellsville Coal	Second Cow Run Sand	S.E.O., S.W Pa., W.Va.
						Kittanning Sandstone	Gas Sand	Ferriferous Limestone	
						Vanport Limestone			
					800	Brookville-Clarion Coal			
			Pottsville	Cpv	900	Homewood Sandstone	Salt Sand	Tionesta Sand	S.E O., S W Pa., W Va.
						Mercer Coal			
						Connoquenessing Sandstone		Maxton Sand	Kas., I T., S E.O., S.W Pa., W.Va.
		Mississippian	Mauch Chunk	Cmc	1050	Mauch Chunk Red Shale	Red Rock	Mountain Limestone Keener Sand at this horizon	S E O., W.Va.
					1150	Greenbrier Limestone	Big Lime		
			Pocono	Cpo	1200	Burgoon Sandstone	Big Injun Sand	Mountain Sandstone	S.W.Pa., W Va., S E O., E Ky
					1530		Squaw Sand		S W.Pa., W.Va., S.E O., E Ky
					1750		Thirty Foot Sand	Berea Sand (Butler County Gas Sand)	S W Pa., W.Va., O., Ky
					1900		Gantz Sand	First Sand } Hundred Foot	W Pa., W Va., S.W O
					1950		Fifty Foot Sand	...... } Hundred Foot	W Pa., W Va.
	Devonian	Upper	Catskill		2050		Ninevah Thirty Foot Sand	Second Sand	W.Pa., W.Va
					2100		Gordon Stray Sand	Gray or Bowlder Sand	W Pa., W.Va.
					2130		Gordon Sand	Third Sand	W.Pa., W.Va., S E.O.
					2200		Fourth Sand		S.W.Pa., W Va
					2300		Fifth Sand	McDonald Sand	S.W.Pa., W.Va.
					2400		Bayard Sand	Sixth Sand	S W.Pa., N.W.Va.
			Chemung		2500		Elizabeth Sand		S.W.Pa., N.W.Va.
					2700		Warren First Sand		N W Pa.
					2750		Warren Second Sand		N.W.Pa.
					2935		Tiona Sand		N W.Pa.
					3100		Speech Ley Sand		N W Pa
					3300		Cherry Grove Sand		N.W.Pa., W.N Y
					3415		Cooper Sand		N.W.Pa., W.N Y
					3525		Deer Lick Sand		N W.Pa., W.N Y
					3750		Elk Sand		N.W.Pa., W.N.Y
					3925		Kane Sand		N W Pa., W N Y.
		Middle							
		Early			5325	Black Shale			N.W.Ky. So.Ind.
			Hamilton		5330	Hamilton Limestone			N.Y.
			Corniferous		5625	Corniferous Limestone			So Ind., C.N Y
					5660	Oriskany Sandstone			
	Silurian	Upper	Niagara		5700	Guelph Limestone			W.N.Y.
					5820	Niagara Limestone			W.N.Y., Ind.
		Lower	Clinton		6000	Clinton Limestone			S.E O.
			Medina		6085	Medina Red Sand			W N Y., O.
					6250	Medina White Sandstone			C.N Y
			[illegible]		[illegible]	[illegible]			[illegible]

Fig. 2 General Divisions of Geologic Time

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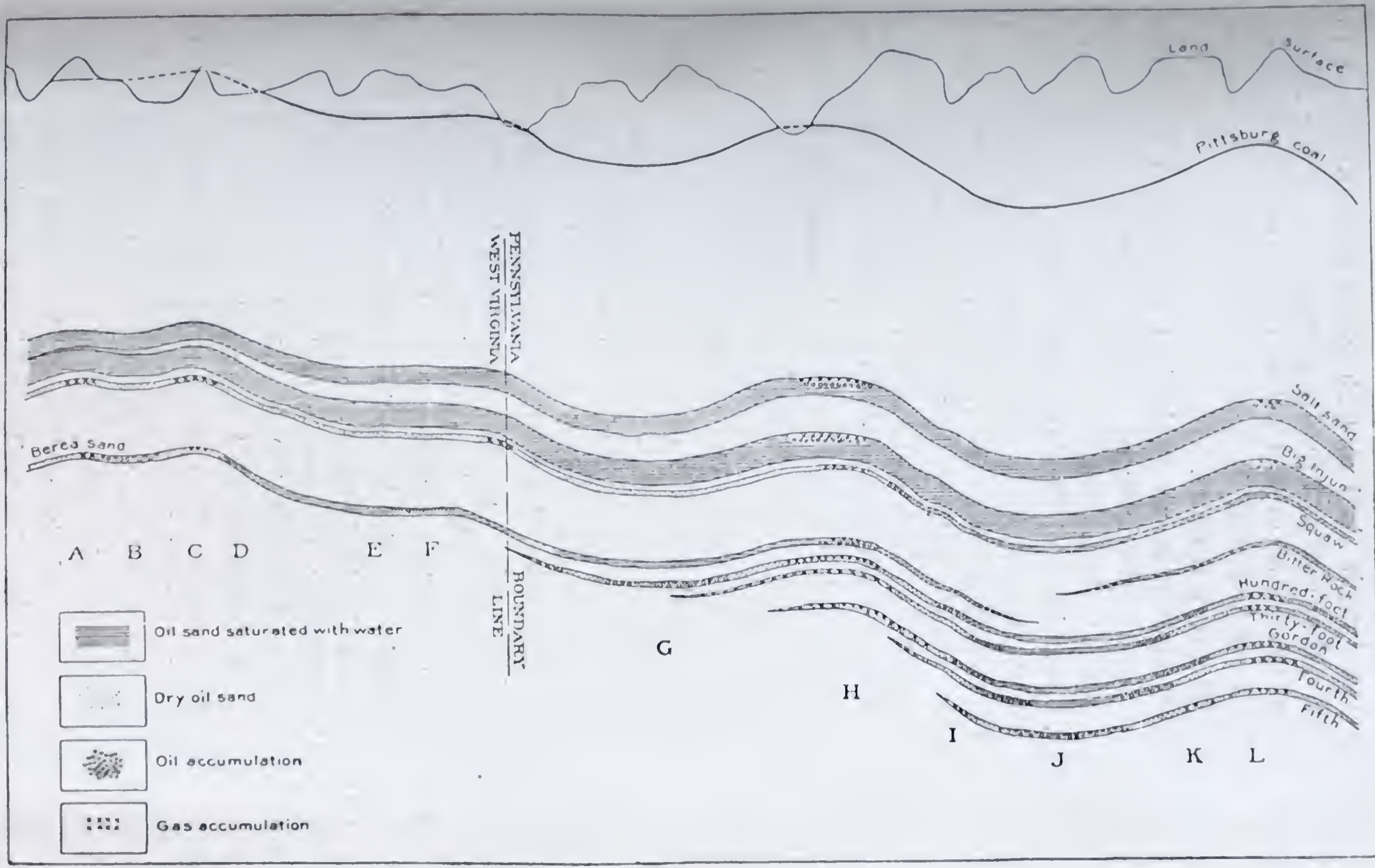


Fig. 3. Geological Cross Section, Central Appalachian Oil Field, West Virginia—Pennsylvania

tion of the Pittsburgh Coal and showing how from east to west the strata thin out and finally disappear. In the Appalachian region the Pittsburgh Coal is the plane of reference. It is easily identified and is very constant in occurrence throughout the entire district.

Petroleum occurs in all geological formations from the Lower Silurian or Ordovician up to the Miocene Formations of the Tertiary. It is of commercial importance chiefly in the Silurian, Devonian and Tertiary rocks. The Carboniferous strata are usually too broken and lie too near the surface to retain it. An examination of the records of deep well drilling in various sections of the United States will indicate in a general way the depth to which wells are to be driven in reaching productive strata and thereby enable us to arrive at an understanding of the types of derricks to be used in particular localities and the loads which must necessarily come upon them. It is apparent that no one type or weight of drilling mechanism will be adapted to all fields. The conditions which have to be met in drilling a well 200 feet deep are quite different from those found in wells of twenty to twenty-five times that depth.

The early wells were drilled with a spring pole. The deepest well drilled in the United States was located on the William Bedell farm near West Elizabeth, twelve miles south southeast of Pittsburgh, and was put down by the Forest Oil Company in 1898. The depth of this well was 5575 ft.; its head was 130 ft. below Pittsburgh Coal and its bottom in the shale supposed to be the Marcellus and probably not more than 100 ft. above the horizon of the Corniferous Limestone. At the depth of 5500 ft. the crown pulley broke, cutting the rope and dropping the tools 100 ft., which caused a stay of proceedings. To drill this well required extra heavy machinery consisting of two 25 h. p. engines and boilers, three bull ropes, 16 in. belt, 13½ foot band wheel, 5 in. forged shaft. two brakes on the bull wheels and two cables spliced together. The weight of the cables was about 14 000 lbs., and the approximate cost of the well was about $40 000.00. It was the expectation that this well would reach oil in the Corniferous. The only well in Pennsylvania which has been

drilled through the entire series of the Devonian Measures and into the Corniferous was the Conway well 8 miles south of Franklin, Venango County, which reached this horizon at 3880 ft., starting of course very far below Pittsburgh Coal.

At the extreme northeast of the Appalachian Measures in Pennsylvania is the Gaines Pool. Sixty-five wells have been recorded from the Atwell Sand with an average depth of 828 ft., ranging from 705 to 1063 ft. Twenty-four wells are recorded from the Blossburg Formation with an average depth of 599 ft., ranging from 545 to 907 ft.* The Venango and the Butler Sands lie in the Catskill Formation. The average of those wells in Butler County of which records are at hand show a depth of 1596 ft.

In *Bulletin* 304 *of the United States Geological Survey* 170 wells in Greene County are recorded as follows:

18	in the	Big Injun	with an average depth of	1910	ft.
2	"	Gantz	" "	2414	"
7	"	Fifty Foot	" "	2592	"
41	"	Ninevah	" "	3152	"
15	"	Gordon	" "	3105	"
14	"	Fourth Sand	" "	3183	"
35	"	Fifth Sand	" "	3118	"
38	"	Bayard	" "	3054	"

The average depth of the 170 wells is 2961 ft.; the shallowest well, 1528 ft., in the Big Injun, and the deepest, 3651 ft. in the Elizabeth Sand just below the Bayard. The average depth figured from 169 wells to the Pittsburgh Coal is 779 ft.; to the Big Injun averaged from 165 wells, 2008 ft.; to the Fifty Foot averaged from 135 wells, 2788 ft.

In *Bulletin* 300 *of the United States Geological Survey* are found records of wells in the Amity quadrangle, Washington County, giving average depths of wells as follows:

11	wells in the	Big Injun	1615	ft.
3	" "	Thirty Foot	2264	"
95	" "	Gantz	2351	"
83	" "	Fifty Foot	2418	"
2	" "	Gordon Stray	2375	"
8	" "	Gordon	2309	"
4	" "	Fourth Sand	2730	"
51	" "	Fifth Sand	2634	"
12	" "	Bayard	2807	"
53	" "	Elizabeth	2910	"

* Twenty-second Annual Report of the United States Geological Survey, Vol. 3.

Average of the 322 wells, 2500 ft. Shallowest well 1400 ft. deep in the Big Injun; deepest well 3137 ft. in the Elizabeth Sand.

Table 3 gives a complete list of wells in West Virginia compiled from *Vol. 1-A of the West Virginia Geological Survey.*

In Ohio the great oil bearing strata is the Berea Sand. In Harrison, Belmont and Guernsey Counties according to *Bulletin* 346 *of the United States Geological Survey* the average depth of 68 recorded wells is 1577 ft. In the Steubenville quadrangle according to *Bulletin* 318 *of the United States Geological Survey* the Berea Sand was found by 37 wells at an average depth of 1392 ft.

In Central Indiana (Lima-Indiana Field) 74 wells found the Trenton Limestone at an average depth of 1113 ft.; shallowest 926 ft., deepest 1300 ft.

In the Princeton Field 137 wells found the Huron Sandstone at an average depth of 905 ft. ranging from 855 to 1200 ft.

The wells in Jasper County, Ind., are found in the Corniferous Limestone. W. S. Blatchley* records a well which reached this stratum at 110 ft. The well was drilled with a portable outfit in 23 hours actual working time, which seems to be a record for quick production. The Corniferous Limestone is reached at Terre Haute at 1650 ft.

In the Illinois Fields † wells are found as follows:—

Litchfield—average depth	640 to 670 ft.
Casey County—average depth	30 wells—398 ft.
Crawford County—average depth	29 wells—963 ft.

The wells at Litchfield and in Casey County are usually drilled with a Star portable drilling machine; in Crawford County with a standard 72 foot derrick.

In Kansas ‡ wells reached the Cherokee Shale at the bottom of the Pennsylvania Formation at Coffeyville in 600 ft.; Independence 450 to 600 ft.; Cherryvale 700 to 800 ft.; Neodesha 800 to 900 ft.; Bolton 1100 to 1200 ft.

* Thirty-first Annual Report of the Department of Geology, State of Indiana, 1906.

† Illinois State Geological Survey, Bulletin No. 2.

‡ United States Geological Survey, 1908, Folio 159.

County	Sand	No. of Wells	Depth: Average	Depth: Shallowest	Depth: Deepest
MONONGOLIA	Big Injun	1	2414		
	Gordon	2	3198	3098	3293
	Fourth	13	3206	3001	3495
	Fifth	3	3390	3354	3409
	Bayard	9	3380	3174	3631
MARION	Big Injun	7	2307	1877	2650
	Gordon	7	3127	2967	3340
	Fourth	21	2882	2631	3380
	Fifth	4	3003	2495	3300
	Bayard	9	2982	2750	3333
WETZEL	Cow Run	1	1120		
	Maxton	4	2359	2263	2436
	Big Injun	16	2246	1938	2710
	Gordon	85	2979	2571	3467
	Fourth	7	3156	2781	3496
	Fifth	3	3387	3189	3585
	Bayard	1	3383		
MARSHALL	Cow Run	5	983	904	1055
	Big Injun	1	1465		
	Gordon	28	2849	2477	3108
	Fourth	1	3225		
	Fifth	6	2789	2579	2942
BROOKE	Berea	3	1541	1509	1577
HANCOCK	Berea	16	1240	1107	1359
TYLER	Big Injun	97	1876	1430	2192
	Gordon	22	2861	2568	3139
PLEASANTS	Cow Run	19	717	530	947
	Big Injun	14	1764	1375	2181
	Berea	2	1460	1348	1571
DODDRIDGE	Big Injun	15	2007	1745	2423
	Gordon	50	2832	2314	3206
	Fifth	5	2934	2815	3081
HARRISON	Gordon	36	3061	2742	3433
	Fifth	49	2781	2160	3415
TAYLOR	Dry	4	2625	2400	3019
LEWIS	Gantz	26	2362	1675	2640
	Gordon	7	2759	2517	2936
	Fifth	23	2751	2130	3103
GILMER	Salt	3	1322	1215	1521
	Gantz	3	2243	2160	2293
	Fifth	14	2800	2668	3098
BRAXTON	Salt	7	1773	1610	1985
	Fifty-foot	3	2998	2800	3275
CALHOUN	Big Injun	2	1786	1736	1837
	Berea	17	2230	2143	2409
	Gordon	2	2558	2540	2575
RITCHIE	Carroll	2	320	295	345
	Maxton	22	1612	1469	1917
	Big Injun	72	1885	1568	2134
	Berea	12	2145	1940	2271
	Gordon	3	2563	2498	2675
WOOD	Berea	58	2212	1921	2393
WIRT	Second Cow Run	1	428		
	500 Foot	1	470		
	Salt	2	1849	1795	1902
	Big Injun	2	1544	1128	1960
	Berea	2	1843	1480	2205
	Gordon	2	2249	1890	2608
ROANE	Maxton	3	1814	1700	1951
	Big Injun	1	1838		
JACKSON	Big Injun	2	1726	1670	1782
	Berea	2	2180	2175	2185
MASON	Big Injun	1	1853		
	Berea	2	1759	1677	1840
PUTNAM	Big Injun	1	1895		
	Berea	3	2175	2156	2198
CABELL	Big Injun	4	1525	1381	1660
	Berea	6	2133	2052	2238
	Corniferous	1	2770		
WAYNE	Big Injun	1	1401		
	Elizabeth	2	1984	1845	2132
KANAWHA	Elizabeth	2	2224	1840	2608
FAYETTE	Elizabeth	1	2895		
SUMMERS	Elizabeth	1	3000		

TABLE No. 3.

Oil and Gas Wells in West Virginia

In Oklahoma * the first development of oil took place at Muskogee in 1894 when two wells, one 800 and one 1100 ft. deep, were drilled within the present city limits, finding oil in the Carboniferous rocks of the Mississippian Series. Average depth of wells in Oklahoma 1000 to 1100 ft.

In the Anse La Butte Field, Louisiana, the wells run from 593 to 801 ft.

In the Jennings Field the first well driven by the Southern Oil Company was 1821 ft. The wells range from 1510 to 2230 ft., with an average of 1845 ft., the most of them running from 1700 to 1900 ft. deep.

Oil occurs in the Spindle Top Field, Texas, in the Miocene. Shallowest well 772 ft.; deepest 1111 ft.

In the Sour Lake Field five wells were drilled in 1898 producing oil, none of them over 280 ft. deep. The oil is found from 230 up to 1400 ft., and the deepest well of this field was 1612 ft.

In the Batson Field oil is found in the Columbia strata of the Miocene. The wells run from 790 to 1159 ft., averaging around 1100 ft. The mutual relations of gas, oil and saltwater which are reported as typical in the Appalachian Field are better exemplified in the Batson Pool than in any other pool in the Gulf Coastal Plain. The wells are usually drowned out by saltwater.

In the Saratoga Field the wells are generally 800 to 1000 ft. deep.

At Matagorda they run from 859 to 875 ft.

At Dayton, Texas, the wells are 600 to 700 ft. deep.

The shallowest producing wells in the United States are probably in Nocogdoches County in which field the wells run from 70 to 200 ft. deep. In the larger majority of cases the oil is found in wells not over 100 ft. deep.

The wells of Louisiana and Texas are found in what is known geologically as the Gulf Coastal Plain. The deposits for 500 to 600 ft. deep are alluvial interspersed by sand, blue clay, marl and mud. The oil is found in domes which have been thrown up by geological changes and in which suitable

* Oklahoma Geological Survey, 1908, Bulletin No. 1.

conditions obtain for the storage of oil in the Miocene Limestone underneath an impervious cap. The Miocene Limestone is dolomitic in character. The oil wells are found on the sides of the dome, the gas at the top and the saltwater farther down. Just outside the restricted limits of the productive area the limestone changes its character from dolomite to ordinary calcium carbonate or disappears entirely. These wells are high pressure and large volume but short duration.

The wells of California are found in the Cretaceous and as a rule are very much deeper than in the Appalachian Field. The deepest producing well in the world is believed to be a well of the Los Alamos Oil Company near Los Alamos, Cal., in the extension of the Santa Maria Field. It is 4350 ft. to the bottom and has yielded 600 barrels a day of 35 degrees gravity oil. The drilling of this well required two years which is not uncommon in some California districts.

From this discussion it is apparent that we are now in a position to give an answer to the question "How deep is an oil well?" and to arrive at some conclusions as to the stresses which will come upon drilling mechanism, the loads that will have to be carried, etc. In addition to geological conditions as affecting the depth of wells the character of the stratum through which the well has to penetrate determines the character of the equipment. The rocks of the upper Appalachian Field lie almost level and are hard in texture so that the drill can penetrate them and leave a vertical self-supporting wall. In the West Virginia Field as already intimated, the method in use in Venango County proved inadequate for drilling through sands and shales that broke, caved and fell into the wells. In California the strata lie at high inclinations and the rocks are soft and cave readily. It, therefore, becomes necessary to provide means for the under-reaming of the material in order to maintain the well in a vertical position, and to do this the derrick is equipped not only with the operating mechanism customary in the eastern field, but also with a calf wheel to carry the reaming tools. This difference in the design of machines is due solely to geological conditions.

TYPES OF WELL DRILLING MECHANISM

It is very apparent from this discussion that one type of well drilling machine cannot very well accommodate all the various conditions met with in the oil and gas fields. The essential idea of drilling is the dropping or striking of a steel chisel into the ground and to all intents and purposes was embodied in the use of the spring pole with which the first wells were driven. The natural and best known successor of the

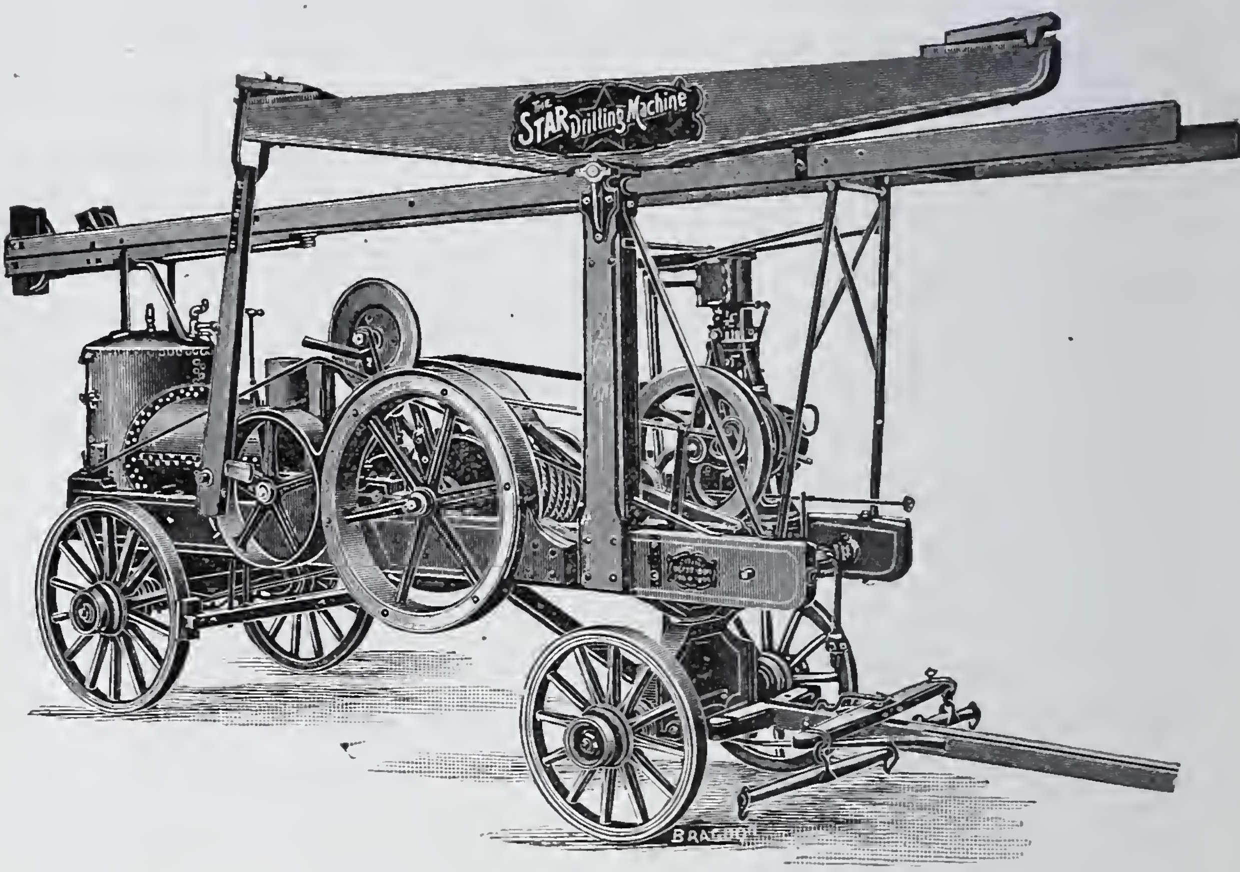


Fig. 4. Star Drilling Machine

spring pole is the cable system with its four legged braced wooden derrick with mechanism for the raising and lowering of tools, casing, cleaning devices, etc. Before we take up this standard type of construction it may be well to refer to other types which are met with in different fields and which have their proper places.

The shallow wells in Illinois are usually drilled with a Star Drilling Machine, Fig. 4, made at Parkersburg, W. Va., which is also extensively employed in the drilling of water wells. This machine is made of wood and has engines, boilers and mechanism mounted on the same truck. It is not likely

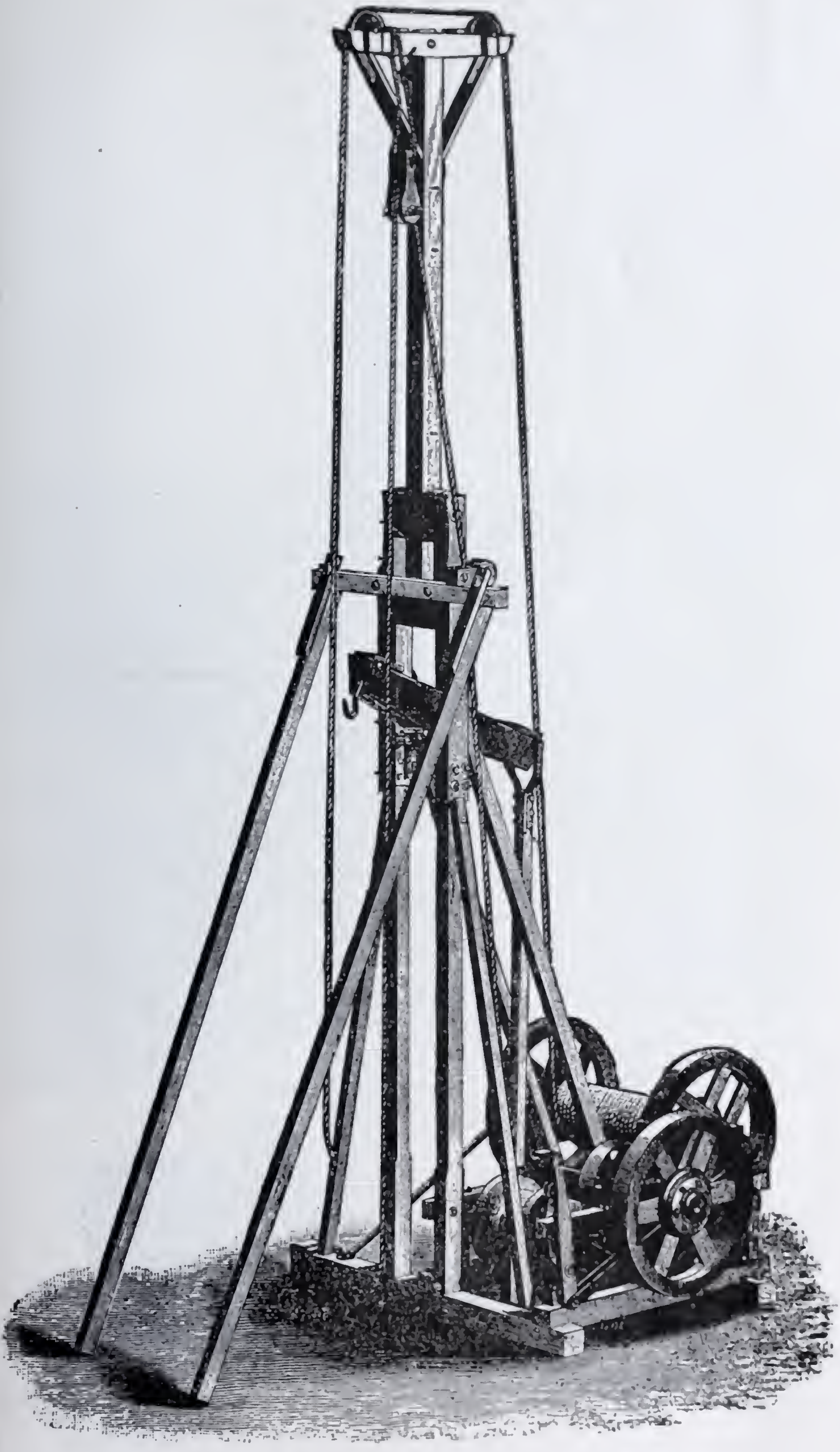


Fig. 6. Corbett Portable Drilling Machine

Fig. 7. National Portable Drilling Rig

that this machine would be efficient for drilling wells more than 300 or 400 ft. deep.

In deeper but comparatively shallow wells, say up to 1000 ft. deep, the most economical mechanism is the portable drilling rig of which the Columbia Driller shown in Fig. 5 may be taken as the most approved type. It is simply the Star Drilling Machine modified for heavier service. The boiler is now mounted on its own foundation, but the trucks still carry an engine with walking beam, band wheel, etc., with a stiff

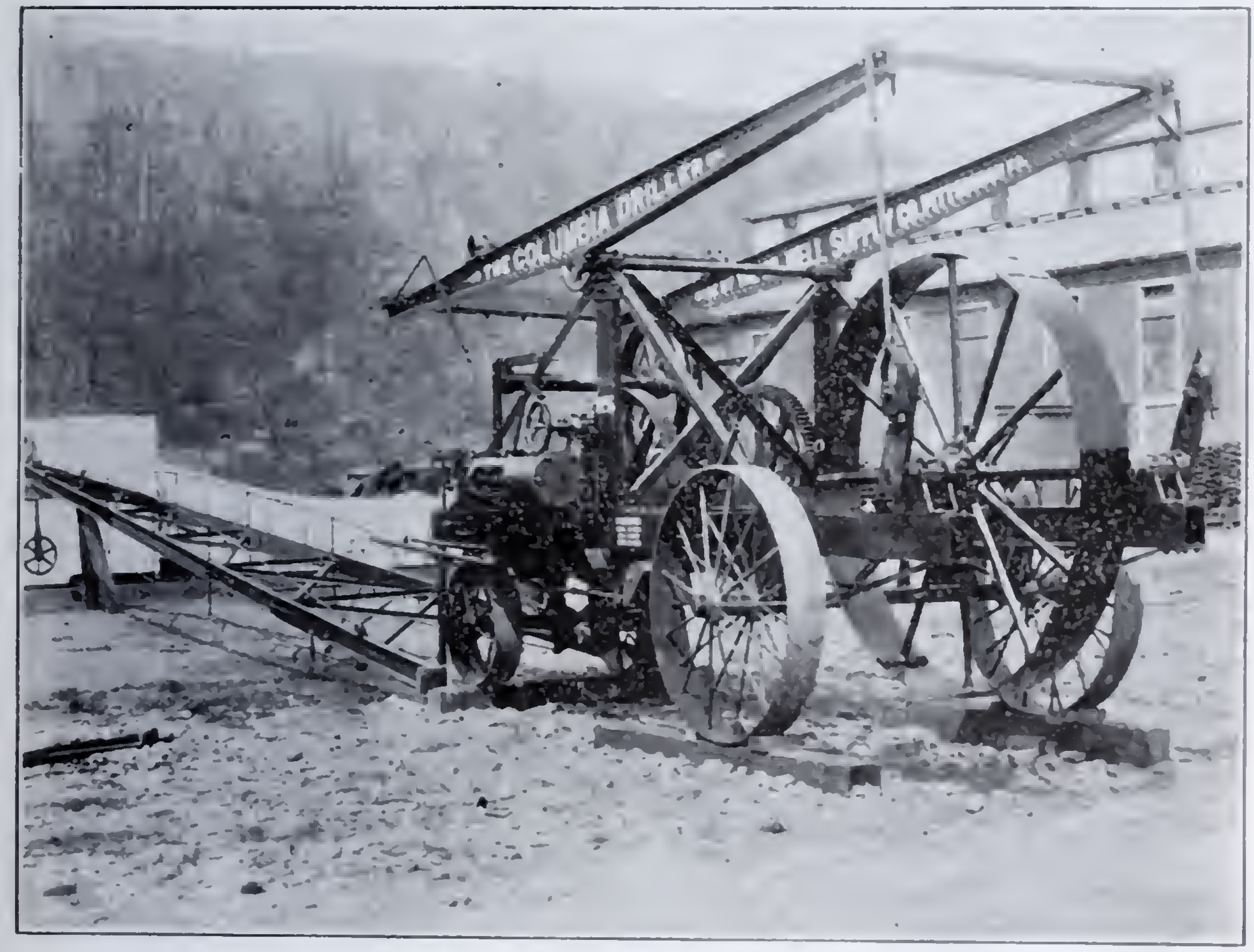


Fig. 5. The Columbia Driller

leg mast secured during operations to the frame of the derrick and having a crown pulley to carry a string of tools to draw casing, etc . This derrick is manufactured in several different weights and sizes, and has a wide range of usefulness.

The Corbett Portable Drilling Machine shown in Fig. 6 is not recommended for wells over 600 ft. deep, though wells have been drilled with it 1000 ft. in depth. It consists of a wooden mast carrying two balanced crown pulleys at its top with attachments for sand lines and a triangular braced

stiff leg pedestal. The band wheel, bull wheel and sand reel are mounted on their own separate truck. The engine has been separated from the other parts of the drilling mechanism. The band wheel is driven by a belt from the engine. The sand reel is operated by friction applied by a lever. The bull wheel is also operated by friction or by a chain and a clutch.

The National Portable Drilling Rig, Fig. 7, is an extension and simplification of the Corbett Rig, and has been in successful use for drilling wells up to 1600 ft. deep, and is claimed to be sufficient in its heavy form for the drilling of wells 2500 ft. deep. The regular rig will handle 1000 ft. of 6- 5/8 in. casing weighing 17 lb. per lineal foot. The drilling rig consists essentially of a mast 60 ft. high and 39 ft. wide at the base in three sections. The legs are made of Georgia yellow pine and trussed throughout their entire length with 1 in. and 2 in. pipe braces. The bull wheels are 7 ft. in diameter; the band wheel 9 ft. and sand pulley 18 in. in diameter suspended from a hook on the side of the derrick in such a manner that the sand line runs in a straight line to the sand reel. The sampson post is dispensed with and the walking beam, which is 12 ft. in length, is suspended between the two legs of the derrick. This arrangement reduces the working space to a minimum and makes possible a very compact structure though necessarily of limited range.

It is apparent that a single mast drilling rig is not adapted to deep wells where heavy loads need to be carried and where exceeding stiffness is absolutely indispensable. The Knupp Rig, Fig. 8, is intended to possess portability as well as stiffness. The base of the braced mast has been widened. It is also stiffened by triangular frames and guyed by wire guy lines. The band wheel, sand reel and walking beam have been placed on their own independent foundation. This type of construction has been used in drilling wells as deep as 3500 ft. It has not, however, so far as the writer can learn come into very extensive application, presumably by reason of the expensive character of the guying necessary and the disadvantages connected therewith.

These disadvantages, at least so far as deeper wells are

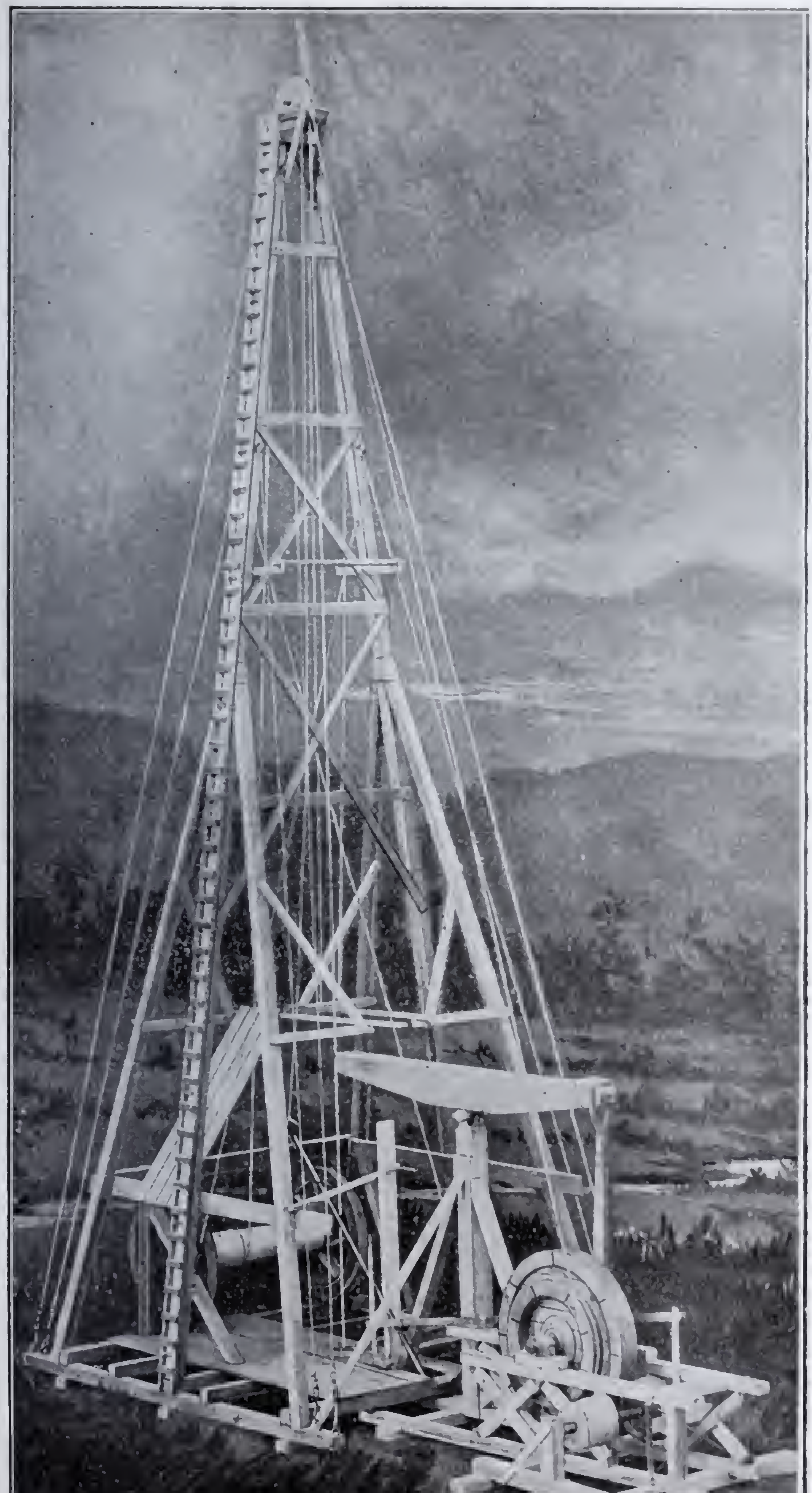


Fig. 8. The Knupp Portable Drilling Rig

concerned, affect all the types of portable drilling machines, especially where the portability consists in the mounting of the entire mechanism on trucks for ready transportation. The obvious advantages of such a rig which may be freely moved about are such that many attempts have been made to produce one of sufficient power to compete with the standard drilling rig. These efforts have usually resulted in disappointment. Expense is necessarily incurred in the use of high priced material in the way of guy lines, and it need not be said in this presence that the use of any external means of support is contrary to the principles of structural design which requires all loads and stresses to be taken care of within the structure itself, and experience indicates that where strength and stiffness are required such as is necessary in the drilling of deep wells the simplest form of construction complete in itself and in conformity with engineering principles will after all be found to be the most economical and satisfactory. The portable drilling rig, however, has its place. It is adapted for shallow wells and it also will be a useful instrument in the future for the cleaning out of deep wells drilled with a standard rig. In the vast majority of cases there is no reason why the standard wooden rig should be left permanently in place. Time was when the individual wells were pumped by their own separate equipment; now many wells are connected together for pumping purposes, and it seems but reasonable that the deep wells of the future will be drilled by a standard steel drilling rig of great strength and stiffness, and will be cleaned after the standard rig has done its work and gone elsewhere by portable drilling rigs caring for many wells in the same pool.

The oil wells in the Gulf Coastal Plain of Texas and Louisiana as already explained, are found in the dolomitic limestone which underlies Pleistocene deposits of sand, gravel, marl and clay, and for situations of this character the hydraulic rotary process has proven itself well adapted, so that it is used almost exclusively in the Texas and Louisiana Fields. The operation consists in rapidly turning a column of pipe, the lower end of which is armed with a steel shoe having a serrated edge for cutting the formations through which it passes. In addition to

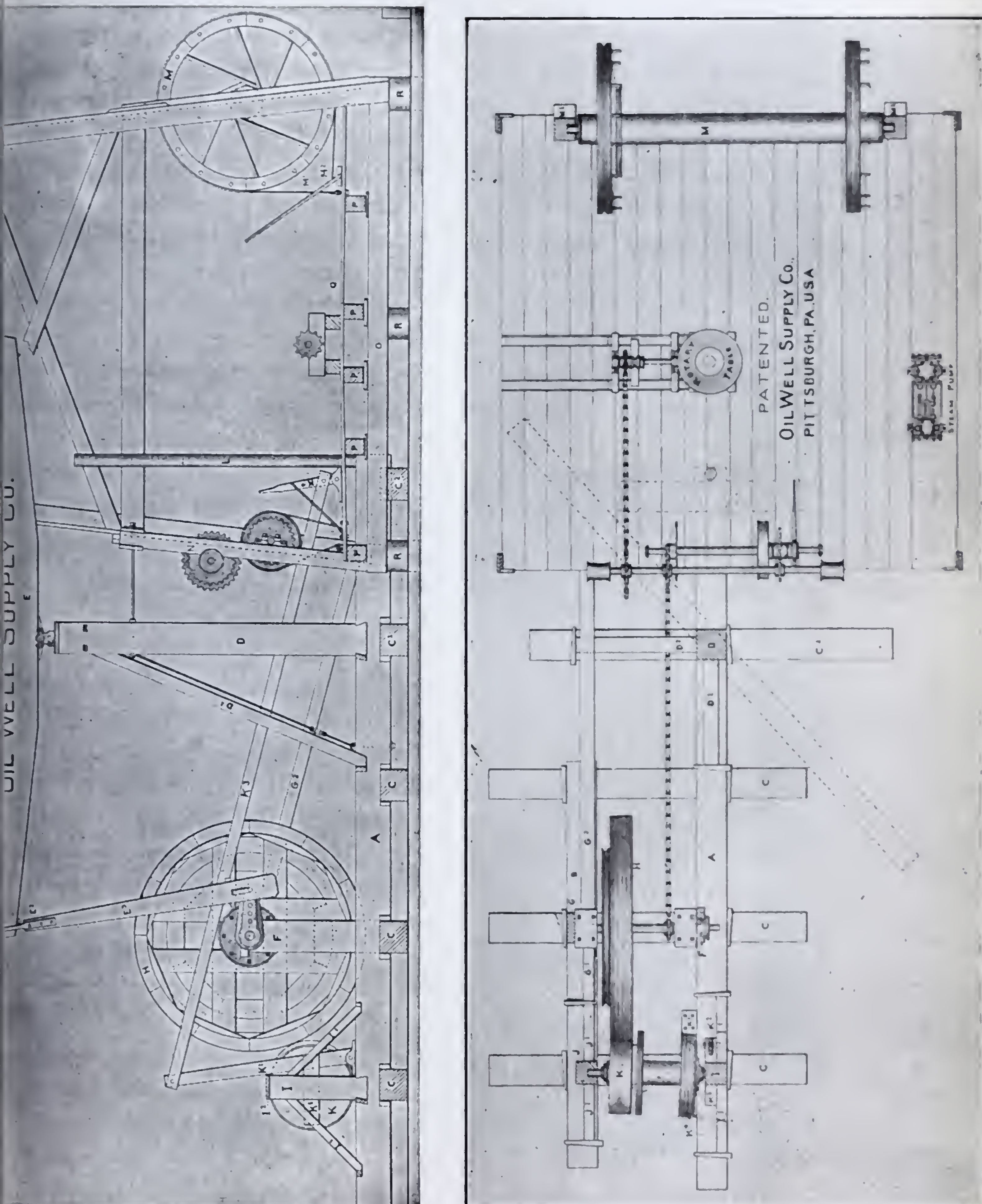


Fig. 9. Rotary Process Combination Rig

the derrick used with a cable system, engine hoisting apparatus, etc., the rotary process requires the use of a pump by means of which water is kept under high pressure in the pipe and detritus is forced to the surface, passing up on the outside of the pipe with the water. By this means it is possible to sink a column of casing through the most stubborn beds of quicksand or other soft formations which will not by reason of their lack of stability admit of the usual procedure of first drilling a hole and then lowering a casing to form the final and lasting wall of the well. In very many cases the hydraulic rotary process can be used in combination with the cable system where deep wells are to be driven through hard strata overlain by softer material. In such cases combination rigs are furnished which consist of the rotary equipment combined with a standard drilling rig carrying a walking beam, band wheel, etc., which latter parts are not required in the rotary process proper. Fig. 9 shows the arrangement of mechanism in this process.

Fig. 10 shows the standard derrick which is of almost universal use in drilling oil and gas wells. It is made of ordinary commercial grades of pine or hemlock lumber in sizes stocked at the lumber yards, can be readily framed by ordinary carpenters with the use of the simplest tools and possesses a range of sizes, strength and stiffness sufficient to conform to all requirements. It will be noted that as a result of experience in the construction of derricks for drilling all sorts of wells since the days of David and Joseph Ruffner this type of construction conforms to standards of engineering excellence and its successful use is beyond question due to the combination of good principles of design with cheapness of manufacture. Were it not that timber is deteriorating in character while increasing in cost and is not adapted for removal and re-use without a large percentage of loss, the future would require no better construction and the advocacy of the use of steel in the construction of oil derricks would be in vain.

This wooden derrick is ordinarily erected without gin post or other scaffolding. The panels are made of such height that the girts at their tops may be easily reached by a workman

standing on planks at their bottom. The erection proceeds easily and rapidly.

ESSENTIAL PARTS OF A DRILLING EQUIPMENT

The essential parts of a drilling equipment may be divided into two divisions; those that may be regarded as tools and, therefore, capable of easy transport from place to place; and those which belong to the structure. The first division is usually furnished by the drillers as part of their contract for the drilling of the wells; the latter division is furnished by the owner or operator.

1° The tools of a drilling equipment are:

The engine for the operating of the machinery, and the boiler in case steam is used.

Fig. 10. Standard Wooden Oil Derrick—Cable System

The belt, usually of canvas, from the engine to the band wheel.

The driving ropes, which are usually manilla cables, from the tug wheel of the band wheel or its outer pulley to the bull wheel or calf wheel respectively.

The bull wheel rope which is wound around the bull wheel shaft, passes over the crown pulley and through the temper screw to the string of tools.

The sand line which passes from the sand reel over the sand line pulley to the sand pump.

The string of tools.

The string of tools, as the steel chisel with its accompaniments is called, consists of:

A temper screw 5½ to 7 ft. long attached by a hanger to the walking beam.

A rope socket 2 to 4 ft. long which clamps the bull wheel rope.

A sinker 16 ft. long which adds weight to the blow.

Jars 5½ ft. long which enable the drilling bit to fall suddenly into the well producing a percussive blow.

The auger stem 16 to 48 ft. long.

The drilling bit 4½ to 6 ft. long.

These are not all necessary in all wells, but the derrick has to be high enough to accommodate the whole line of drilling tools. During drilling it is necessary to stop occasionally and remove the accumulated detritus in the well hole. This is done by the use of the sand pump or bailer, the necessary strainers, etc.

2° The parts of the drilling equipment belonging to the structure are:

The crown pulley located on the crown block at the top of the derrick.

The sand line pulley at the same elevation, and in case of a California type derrick an additional sheave and sand pump pulley.

The bull wheel consisting of a solid oak shaft, called the bull wheel shaft, carrying on its outer end a brake wheel rubbing against a steel band brake and a spool for the division into two portions of the bull wheel rope coiled on the shaft; and on its inner end a wheel with a single or double grooved periphery for the application of the tug ropes from the band wheel tug pulley. Both the tug wheel

and the brake wheel on the bull wheel shaft are fitted with spokes for the purpose of turning the wheels off center.

A calf wheel used in connection with the California type of oil derrick for carrying the under-reamer.

A walking beam, usually white oak, 12 x 26 in. and 24 ft. long mounted on a 16 x 16 in. oak timber, called the sampson post.

Under the walking beam is the headache post which prevents movement of the walking beam low enough to injure the workmen, as indicated by its most significant name.

A band wheel, which is the prime mover of all the operating machinery.

A sand reel which carries the wire line to the sand line pulley.

At the end of the band wheel shaft the wrist pin engages the pitman which is suspended by a stirrup from the walking beam to which it imparts a reciprocating motion in a vertical plane. The band wheel is driven by a belt from the engine and in turn drives the bull wheel shaft by a manilla cable passing from the tug wheel on its outer face to the tug wheel mounted on the bull wheel shaft. It also by friction imparts motion to the sand reel which by its winding and unwinding raises and lowers the sand pump and cleaning tools into and from the well just as the bull wheel by the winding and unwinding of the bull rope carries on the operation of the drilling and raises and lowers casing, etc.

The derrick is a four legged braced structure raised on mud sills arranged so as to support its four corners and to carry the derrick floor through which passes the upper end of the well casing. These sills are also arranged for the proper emptying of mud, water, etc., raised from the well by the sand pump or bailer. The machinery supports, such as the sampson post, the inner and outer jack posts which carry the band wheel shaft and the knuckle posts which carry the sand reel shaft, rest in turn on sills which may or may not be connected with the derrick proper. The outer knuckle post is arranged so as to move freely about its axis and carries the swing lever by means of which the sand reel is placed in gear when the sand line is to be used and thrown back against the back brake

when not needed. The back brake is a solid block of soft wood which retards by friction the speed of the reel. The whole structure in the winter season is covered by a house for the convenience and comfort of the workmen, and a ladder is also provided up the derrick for the convenience of the workmen in oiling crown pulleys and making necessary repairs.

LOADS ON THE DERRICK AND MACHINERY

The geological conditions which determine the depths of wells also determine the loads which come upon the derrick. The walking beam has to carry only the weight of the bull rope and the string of tools. The sand line carries the weight of the mud pump, cleaning equipment, etc. Both of these are light in comparison with the loads that come on the crown pulley when casing is being placed in position or withdrawn from the well, and in the ultimate analysis, therefore, the heaviest loads are due to the weight of the casing. Inasmuch, therefore, as the casing remains permanently in position the drilling derrick must necessarily be heavier than a derrick used only for cleaning purposes and it is by reason of this condition that a portable derrick which can only drill wells to a thousand feet deep may be used to clean wells three times that depth.

It will be remembered that the use of casing was invented by David and Joseph Ruffner as a result of their early experience with the salt wells in Kanawha County, W. Va. Every well requires some casing in its construction. In some a single column is sufficient; in others several are needed, each column being of a size to pass through the preceeding column with the least possible lost space between the two. Frequently it is necessary to drive columns of pipe instead of inserting them after the bore is prepared to receive them, in which case heavy pipe called drive pipe must be used, and where the geological formation is not well known, it is much safer to use drive pipe from the very start.

The record of a few wells may be of interest in this direction:—

G. W. Brown Well No. 1, Marion County, W. Va., 2929 ft.

deep, is cased with 480 ft. 10 in. pipe, 964 ft. 8¼ in., 1470 ft. 6⅝ in., 1970 ft. $5\frac{3}{16}$ in.

Paddy Hopkins Well No. 1, same county, 2687 ft. deep, is cased with 386 ft. 10 in. pipe, 1020 ft. 8¼ in., 1539 ft. 6⅝ in., 1965 ft. $5\frac{3}{16}$ in.

William O. Efaw Well No. 2, same county, 3380 ft. deep, is cased with 1661 ft. 8¼ in. pipe, 2630 ft. 6⅝ in., 225 ft. $5\frac{3}{16}$ in. liner.

Nimrod Morgan Well No. 7, same county, 2714 ft. deep, is cased with 496 ft. 10 in pipe, 1040 ft. 8¼ in., 1514 ft. 6⅝ in., 1980 ft. $5\frac{3}{16}$ in.

J. M. Miller Well No. 1, Beallsville, Washington County, Pa., 3200 ft. deep, is cased with 15 ft. 13 in. pipe, 414 ft. 10 in., 858 ft. 8 in., 1470 ft. 6½ in., through the salt sand and is tubed clear down with 4 in. tubing.

Thomas Bayard Well No. 1, Waynesburg, Pa., 2965 ft. deep, is cased with 470 ft. 10 in. pipe, 1160 ft. 8 in., and tubed clear down with 4 in. tubing.

Felix Bell Well No. 1, Waynesburg, Pa., 3008 ft. deep, is cased with 9 ft. 16 in. pipe, 174 ft. 13 in., 685 ft. 10 in., 1382 ft. 8 in., 1706 ft. 6⅝ in, 2076 ft. $5\frac{3}{16}$ in.

Sarah E. Eddy Well No. 1, Monongalia County, W. Va., 3192 ft. deep, is cased with 29 ft. 13 in. pipe, 192 ft. 10 in., 1468 ft. 8¼ in., 2244 ft. 6⅝ in., 3109 ft. $5\frac{3}{16}$in.

Haught Heirs Well No. 1, Monongalia County, W. Va., 3486 ft. deep, is cased with 408 ft. 10 in. pipe, 1490 ft. 8¼ in., 2541 ft. 6⅝ in.

In the Felix Bell Well No. 1, the casing weighs 104 232 lb.; heaviest line 29 036 lb. In the Sarah E. Eddy Well No. 1, 111 894 lb.; heaviest line 38 862 lb. In the Haught Heirs Well No. 1, 82 230 lb.; heaviest line 43 197 lb.

All of this casing has to be lowered by the crown pulley and the derrick must be of sufficient strength to support the entire weight of the heaviest line at once and to withstand at the same time the frictional resistance encountered in lowering or pulling. A careful investigation indicates that the loading on the derricks incident to drilling operations may be classified about as follows:

Shallow Eastern Fields. The derrick in ordinary use is 55 feet high and is equipped with crown pulley, sand line pulley, bull wheel, walking beam, band wheel and sand reel only. The drilling of a well of this sort produces a working load of not to exceed 40 000 lb. on the bull wheel rope and about 10 000 lb. on the end of the walking beam. After the wells are drilled and for the purpose of cleaning a much lighter derrick can be employed with a load on the bull wheel rope not to exceed 20 000 lb., and on the walking beam 4000 lb.

In southwestern Pennsylvania and in West Virginia the standard derrick is 80 ft. high, proportioned for a drilling load not to exceed 60 000 lb. on the bull rope and 17 000 lb. on the walking beam.

In California, however, there has been developed an especial type of derrick known as the California type. These derricks are made 72 ft. high and the bull wheel is supplemented by a calf wheel which carries the reamers and other tools used in connection therewith to enlarge the holes in advance of the casing, to maintain the alignment and to save time, which last is a very important element in well drilling. Ordinarily the same size timbers are employed in their construction as are used on the 80 foot derrick in the East. In some cases it is necessary to strengthen the legs of the derricks and bracing, producing what is known as a double derrick. A load of 80 000 lb. on the bull rope is not uncommon in cases of this sort, and instances have been known of the use of a string of casing weighing up to 89 000 ℔. For these deep wells a drilling load of 80 000 ℔. on the bull rope and 20 000 ℔. on the walking beam is not unreasonable. With these heavy loads extra heavy rig irons are necessary, the band wheel shaft being made 6 in. diameter instead of the customary 4½ in.

The weights of the lumber required to build these wooden derricks are approximately as follows:—

55 ft. high—18 foot base—40,000 lb.
72 ft. high—20 foot base—57,000 lb.
80 ft. high—20 foot base—67,000 lb.

Owing to their exposed position on the sides and tops of hills the oil derricks, houses, etc., are subject to high wind

pressures and members must be calculated accordingly. These wind pressures vary in different localities, but the generally assumed load of 30 lb. per sq. in. with conservative unit stresses should take care of all contingencies. This pressure corresponds to a velocity, figured by the ordinary formulas, of 78 miles per hour. A recent storm in Pittsburgh showed a velocity of 68 miles, which would correspond to a pressure of 23 lb. per sq. ft.

CHARACTER OF INDUCED STRESSES

During the operation of drilling and especially when tools or casing are lowered into the wells by the action of gravity the derrick is subject to intense vibratory stresses which increase with the depth of the well. These stresses, however, are not constant in duration, periods of comparative steadiness being alternated with periods of vibratory strain. In no case are these vibratory stresses likely to exist coincident with high wind pressure. The designer of a steel derrick, therefore, must take account of varied conditions. The problem is that of a machine intermittently in motion.

The bull rope from the string of tools or casing passes over the crown pulley at the top of the derrick and is wound around the bull wheel shaft. Any drilling load thereon produces a stress of twice its amount on the bearings of the crown pulley. The loads are not exactly vertical, but the crown block distributes them over the top of the derrick producing direct compression in the legs of the derrick. These stresses are constant from top and bottom and are only increased at the panel points by the vertical increment due to wind pressure. The diagonal bracing and the girts in the tower take wind stresses only except the girts at the top of the second panel from the bottom. The roof of the house is constructed at this level and the girts have to be figured for bending in addition to direct compression.

The upward pull of the bull rope produces vertical compression in the bull wheel posts which is transmitted by bending into the girt at the top of the first panel point or else is converted into tension on the foundations by the anchoring of

the bull wheel posts to the mud sills. The girt at the top of the bull wheel posts is usually made much stronger and stiffer than the other girts at that level. The pull of the driving ropes from the band wheel produces a horizontal stress in these same posts which must be resisted by diagonal bracing. What applies to the bull wheel applies also to the calf wheel and its supports.

The walking beam acts as a cantilever, the load on the temper screw being balanced by the pull on the pitman rod, their combined effect being to produce a vertical compression on the sampson post. The easiest way to figure a walking beam, however, is to consider it as supported at the temper screw and pitman ends and loaded at its center with twice the load on the temper screw. The sampson post needs to be braced for stiffness only, there being very little stress in anything but a vertical plane and no twisting occurs except the very small amount due to the releasing and re-application of the pitman from and to the wrist pin. The jack posts must be anchored down to resist the upward pull of the pitman rod and braced against the derrick by compression braces to resist the pull of the tug rope towards the bull wheel and against the sill underneath the sand reel to resist the pull of the belt towards the engine. The stresses in the jack posts are quite complex; they are simplified, however, by making each brace take stresses of a definite character. The knuckle posts are likewise in a condition of indeterminate stress. When the bailer or sand pump is in the well the wire line with its load produces an upward stress on the inner post acting at an angle of about 25 degrees. This action is not direct for the reason that the drum of the sand reel is usually several feet off of the working line of the derrick, the shaft being set at an angle and the friction wheels beveled to bear against the band wheel. In the construction of the California type derrick this complexity has been recognized and allowed for by the use of a special form of sand reel and a special arrangement of knuckle posts. In the steel rig hereafter to be described the working line of the sand reel has been made practically coincident with the working line of the derrick and this complexity

of stress eliminated; in general, judgment in the arrangement of braces plays a large part in the designing of drilling equipment and must ever be an accompaniment of theories of structural design; the designer will meet intermediate stresses; he will eliminate them wherever possible.

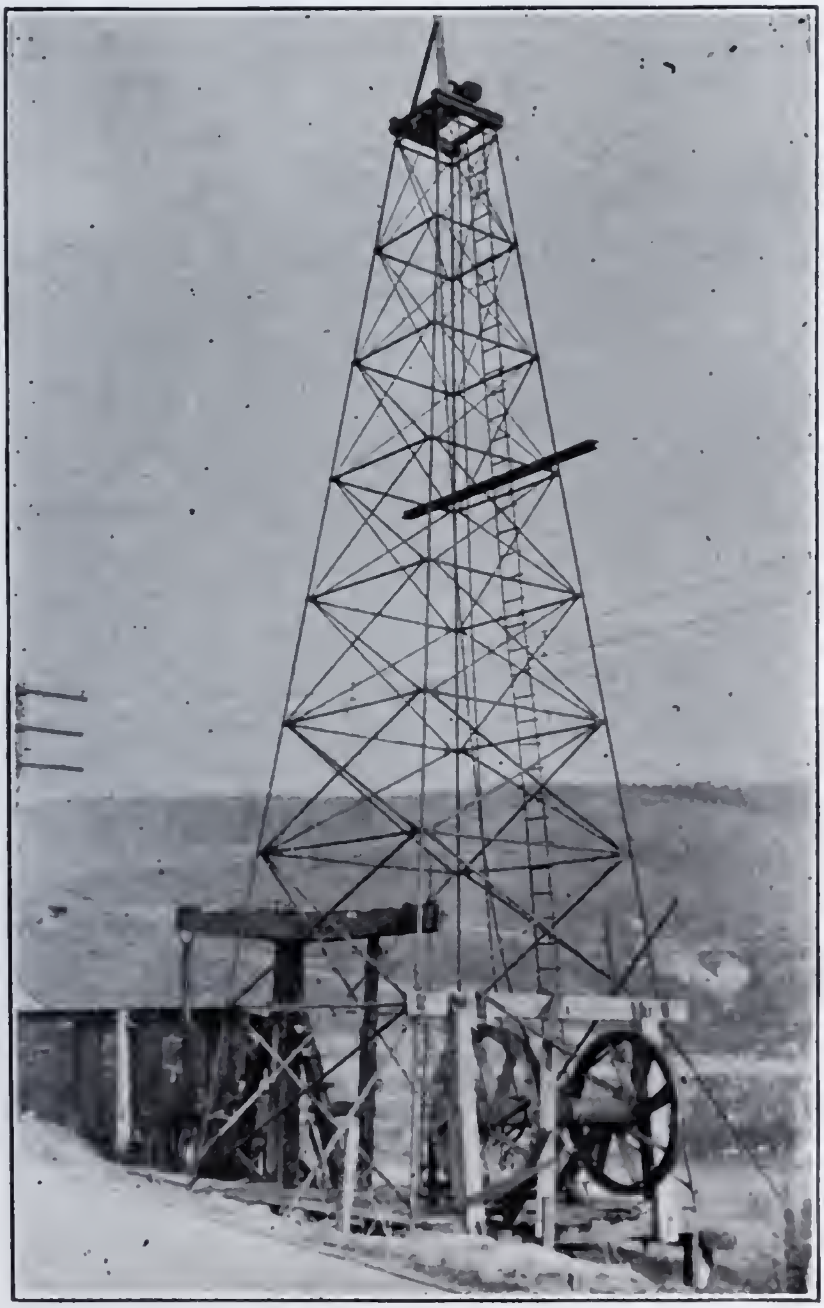


Fig. 11. Gas Pipe Oil Derrick, South Penn Oil Company

The wooden construction of the foundation has heretofore been extremely heavy, much heavier than observation would indicate as necessary. The four corners of the derrick need to be rigidly supported and the floor immediately around the well hole must be strong enough to bear up the weight of two

or three joints of casing, the weight of the string of tools, the sand pump, etc. This usually requires placing transverse joists about two feet each way from the well hole which ordi-

Fig. 12. Steel Oil Derrick—American Bridge Company
1903 Design

narily is 14 in. to 16 in. off the derrick center. A strong transverse sill is needed under the kunckle posts and the jack posts and the sampson post or the longitudinal sills must be strong enough and stiff enough to resist bending. The sill under the knuckle posts also takes an inclined thrust from the engine block brace which abuts against it and it is necessary to provide stiffness in the sill or a counterbrace against the jack post sill.

To meet these stresses the derricks designed under the

supervision of the writer are subject to the following specifications:—

Members in tension under vibratory stress to withstand live load stresses at the rate of 12 500 lb. per sq. in. Members in compression to be figured by the formula:

$$\textit{Unit Stress in lb. per sq. in.} = \frac{50\ 000}{1 + \dfrac{L^2}{36\ 000\ r^2}}$$

with a factor of safety of four, on the assumption that while the derrick may be subject to heavy impact stresses while drilling the deeper sections of the well, these stresses will be of comparatively short duration with frequent intervals of rest and the derrick will have an opportunity to regain its strength even though temporarily overstrained. Wind stresses in tension to be figured on the basis of 25 000 lb. per sq. in. Length of compression member not to exceed 125 times least radius of gyration except when taking wind stresses only. In all cases the dead load of the structure itself to be considered, especially in the lower leg members. Sills to be figured for bending at 16 000 lb. per sq. in. on extreme fibers. At points of concentrated loading webs of beams and channels to be figured to resist buckling by the formula:

$$\textit{Allowable Unit Stress not to exceed} \quad \frac{12\ 000}{1 + \dfrac{d^2}{3000\ t^2}}$$

where d is the depth of the beam and t the thickness of web.

Gusset plates, diagonal braces and other small members to have a minimum thickness of $\frac{5}{16}$ in.; no material of less thickness than $\frac{5}{16}$ in. to be used unless for fillers. Small angles to be used for the diagonals except on the bull wheel side where angles and bars are to be used so as to present a smooth surface for the slack of the bull rope to strike against. The thickness of angles and plates used for bases and for details in the machinery supports to be $\frac{3}{8}$ in. except where increased thickness is necessary to provide proper bearing for

shafts, in which cases the formulas covering the bearing value of pins have their application.

The wind stresses require but very little material in the diagonal braces and horizontal girts and in the ultimate analysis the sizes of diagonal braces are fixed by the minimum sizes considered practicable in good shop workmanship, and the sizes of the horizontal girts in like manner are regulated by the proportion of length to the least radius of gyration.

COMPLETE DRILLING MACHINE 1909 DESIGN

Like all other good things the complete drilling machine manufactured by the Carnegie Steel Company represents the culmination of a development and incorporates in its construction the experience of successful oil well operators and manufacturers of oil well supplies combined with the skill of the engineer trained in the theories and practice of structural design. As already intimated, past endeavors in the substitution of steel for wood in the construction of oil and gas well derricks have been without much success owing to the lack of intelligent co-operation on the part of the operators and the structural designer.

The first metal oil derricks were probably constructed of secondhand steel or iron tubing used in drilling operations with forged connections and diagonal braces made of rods and turn buckles or wire cables. The most recent development of this class of construction is shown in Fig. 11, taken from a photograph made by the writer near McDonald, Pa., illustrating a pipe derrick constructed by the South Penn Oil Company and used over old wells. The legs and girts of this derrick are made of 2½ in. and 3 in. pipe; the diagonal braces of 2 in. and 1 in. pipe; and the ladder of pipe also. The diagonals are fastened together at their intersections by U-bolts, and at their ends they and the girts are forged out flat and fastened to the legs by bolts passing through steel castings which are clamped tightly into position over the abutting ends of the legs by bolts passing through flanges on the outside of the derrick. At the bottom special flange castings are provided into which the legs of the derrick are screwed and which in turn are bolted to

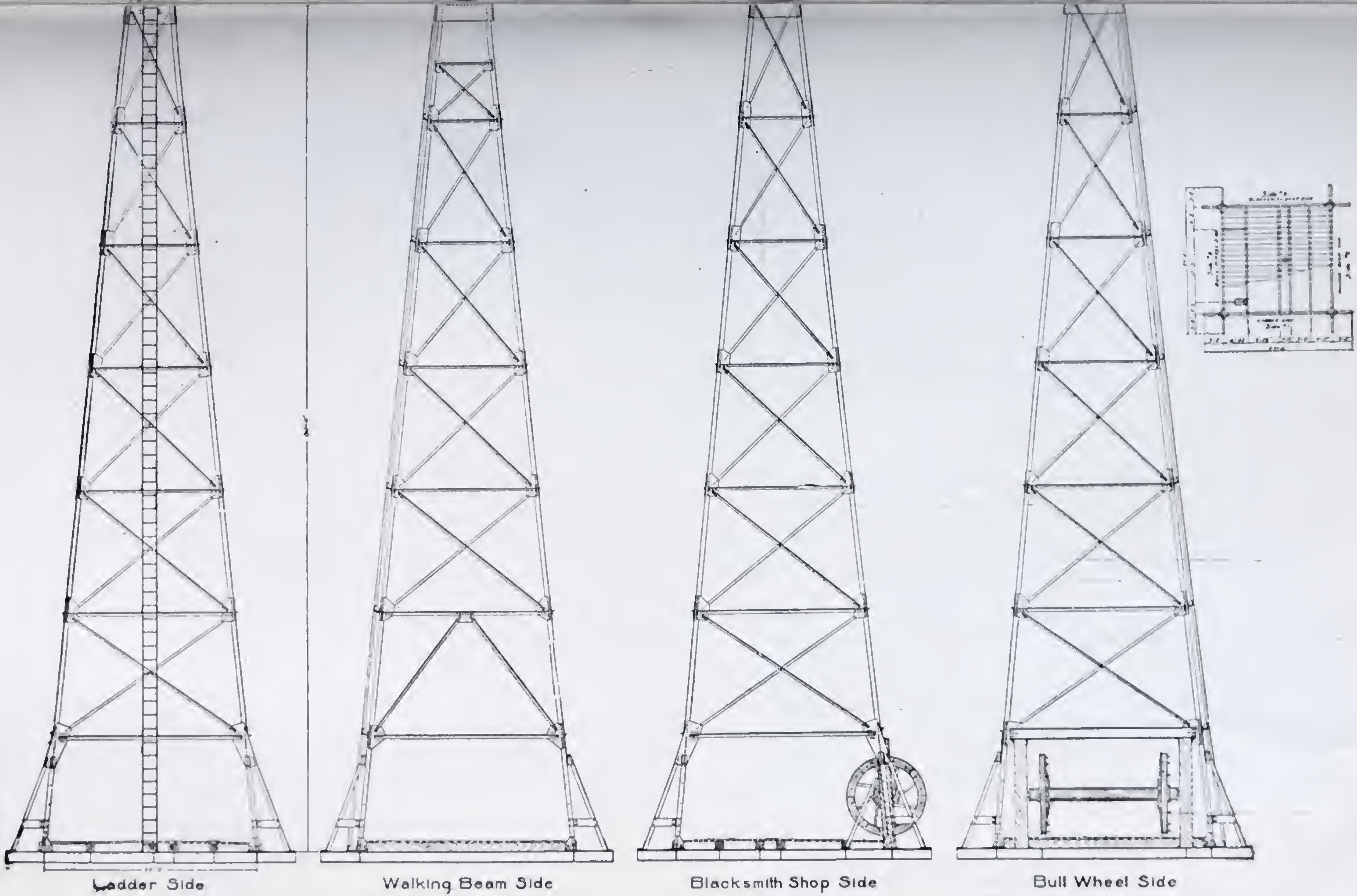
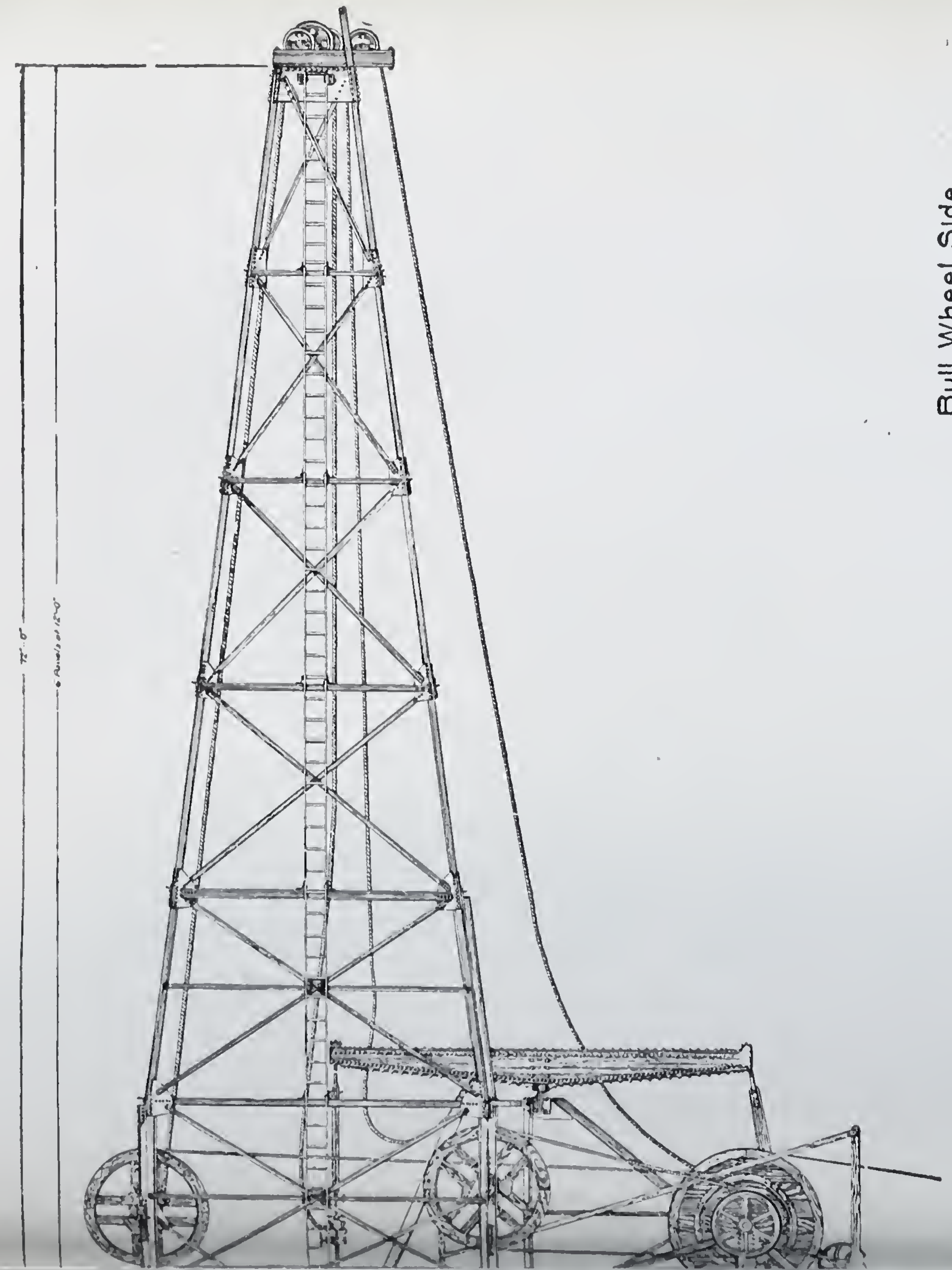
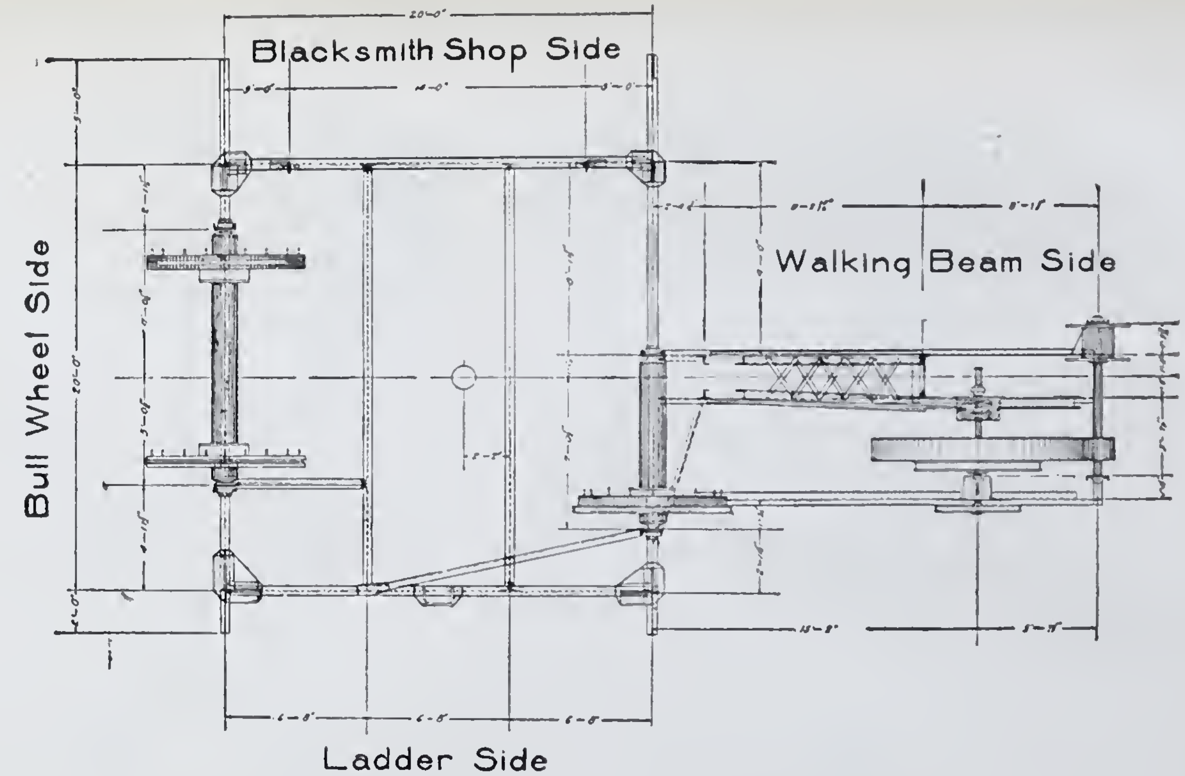


Fig. 13. 80-Foot Steel Oil Derrick, Carnegie Steel Company, 1903 Design





72 FOOT OIL DERRICK

CALIFORNIA TYPE

the sills. The bull wheel turns between white oak posts and the upward strain due to drilling is transmitted as tension into the sills. Special castings are also provided at the top to receive the crown block and the crown pulley. This type of construction seems to be very well adapted for use in cleaning purposes over old wells. It requires six men about three days for its erection complete. The material is obtained secondhand in the oil fields and is, therefore, economical. The forging and special castings would seem to a structural man to be an item of considerable expense. Its chief advantage is that the materials can ordinarily be furnished and the work done by the operators in their own shops. The weight of the derrick proper is about 7000 lb.

A careful calculation, however, indicates that a structural steel derrick of the standard design can be constructed at the same or less expense and possesses elements of stiffness not found in the pipe derrick.

Fig. 12 shows a derrick constructed in 1903 by the Pittsburgh plant of the American Bridge Company, built tower fashion in heights of 50, 60 and 70 ft., with three, four and five panels respectively. The weights of the derricks proper are approximately 9000, 11 000 and 12 500 lb. The legs are 5 by 5 by ⅜ in. angles; braces 2½ by 2½ by ¼ in.; girts 3 by 3 by ¼ in. and 4 by 4 by $\frac{5}{16}$ in.; all connection plates ⅜ in. It will be noted that this derrick has buttresses at the base on all four sides to prevent overturning. It needed for its erection a gin pole or other similar scaffolding. It looked well on paper and the designer's opinion for obvious reasons was not favorand the designer no doubt considered it an excellent thing for the purpose intended. The driller's opinion for obvious reasons was not favorable, and his opinion after all is the only one worthy of consideration.

In 1903 the Carnegie Steel Company built for the South Penn Oil Company and the Carnegie Natural Gas Company twelve oil derricks which were used in the Pennsylvania and West Virginia oil fields. These derricks were 80 ft. high with a 20 foot base and were constructed along the lines of the structural steel tower, as shown in Fig. 13. The derrick proper

weighed 24 000 lb. and provision was made at the top for the crown pulley and at the bottom for wooden bull wheel supports. No endeavor was made to design a complete drilling machine. They proved to be fairly satisfactory, were stiff and steady under strain and have been removed from their original location and re-erected in the drilling of more than one well.

Fig. 15. 72-Foot Steel Oil Derrick, California Type, Carnegie Steel Company 1904 Design, Erected in South America in 1908

In 1904 the Carnegie Steel Company took counsel with the Oil Well Supply Company for the construction of a standard steel oil derrick 72 ft. high with a 20 foot base, California type, and the intention in the design which was produced was to construct proper supports for all the machinery, bull wheel,

etc. This derrick likewise was constructed along the lines of a structural steel tower with high panels requiring the use of gin poles and scaffolding for their erection. Fig. 14 shows their construction which includes a number of improvements in the arrangement of the crown pulleys, the supports for the bull wheel, calf wheel, walking beam, band wheel, etc., one of the most important of which was the location of the sand reel on the working line of the derrick.

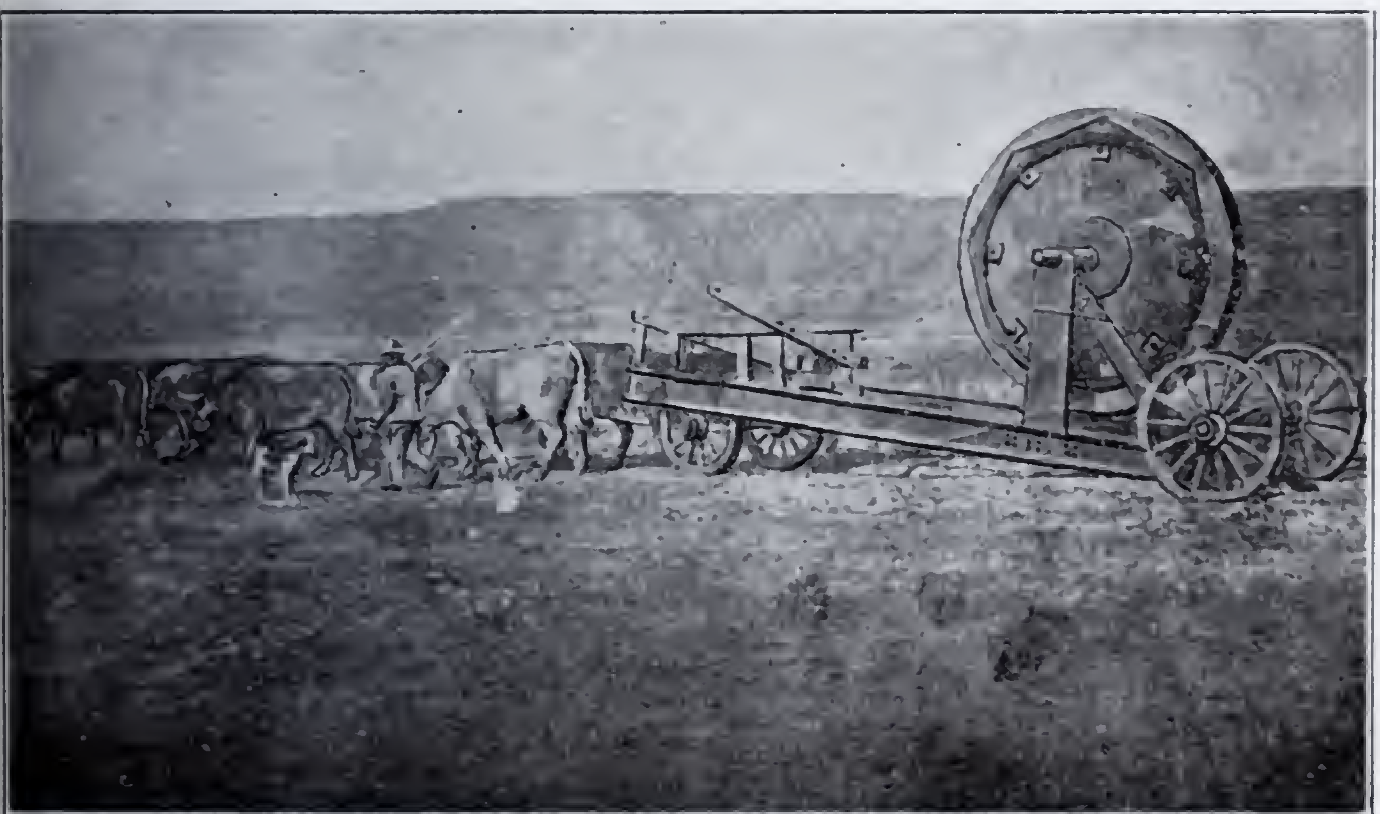


Fig. 16. 72-Foot Steel Oil Derrick Erected in South America
Moving Machinery Supports

The first derricks constructed under this design were shipped to South America for use in the oil fields of Argentine and Peru after the lower panel of one of them had been erected at Upper Union Mills for the proper adjustment of all working parts. The derricks were then shipped to New York via rail and thence via steamer to South America and were hauled inland 300 or 400 miles. The first derrick from which reports were received, shown in Fig. 15, was erected over a well that had been drilled 1000 ft. deep. The drilling was continued 500 ft. further when it was decided to move the derrick to a new location. To do this the sills of the machinery supports

were disconnected from the derrick foundation and the derrick moved bodily on pipe rollers to a new location some two or three miles away. The band wheel sills with the jack posts and band wheel in place were then hauled bodily by ox team as shown in Fig. 16. Fig. 17 shows the character of the country over which the derrick was moved and the means of transportation. After arrival at the new location the parts of the derrick were then connected up again and drilling proceeded. This was a very severe test, but under such unusual conditions the derrick behaved itself admirably without signs of weakness or injury.

Fig. 17. 72-Foot Steel Oil Derrick Erected in South America Moving Boiler

In the consideration of a proper design for a standard derrick the question has been raised as to whether or not it is possible to construct what might be called a collapsible rig, easy to erect and easy to remove, and in this direction a very fertile idea has been brought forward by Mr. Patrick Yorke of the Yorke Derrick Company. Mr. Yorke has introduced numerous improvements in drilling mechanism and practices, one of which is the discovery that in drilling deep wells it is not

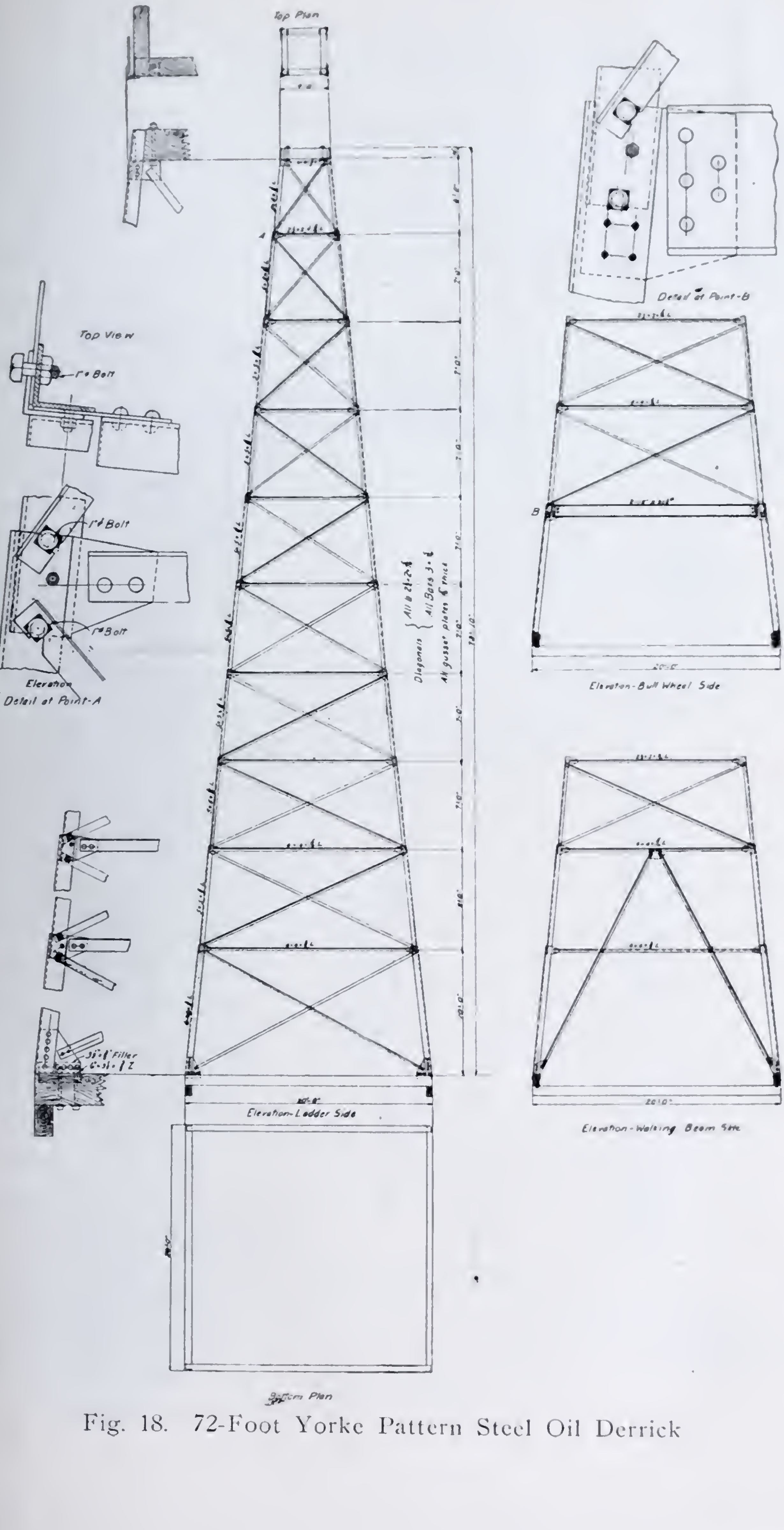


Fig. 18. 72-Foot Yorke Pattern Steel Oil Derrick

necessary to revolve the tools. Anything, therefore, which he presents is worthy of careful consideration. Fig. 18 shows a steel oil derrick built for Mr. Yorke along the lines of his design in wood covered by letters patent. The essential idea is to so arrange the legs of the derrick that they can be slipped

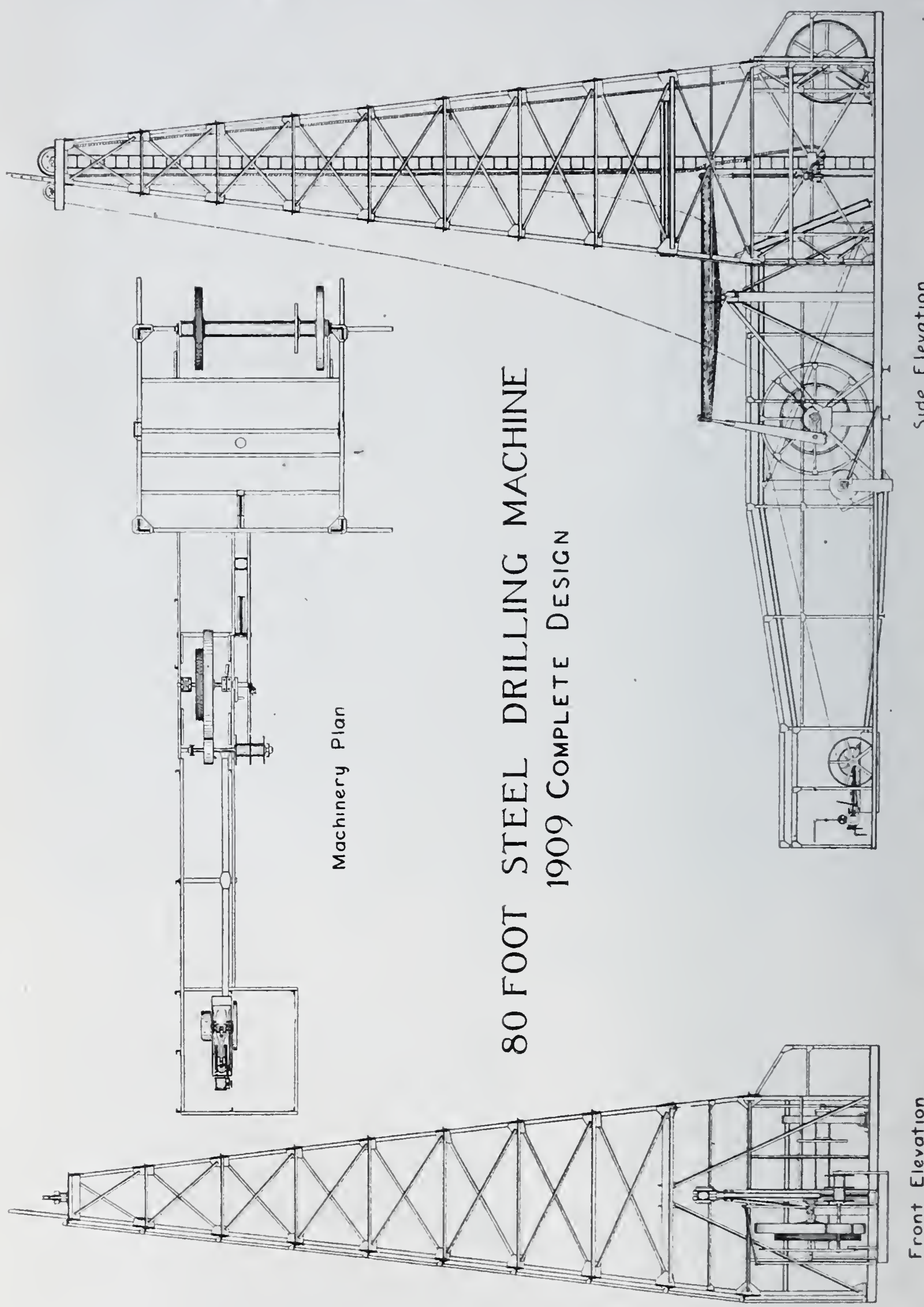


Fig. 19. 80-Foot Steel Drilling Machine, Carnegie Steel Company 1909 Complete Design, General Arrangement Plan

into each other quickly, and the diagonal bracing likewise. The strength of the members to resist wind forces depends on the friction of the angles, etc., against bolts which are secured during erection to the lower members so that the upper members and braces slip readily down over them. Mr. Yorke's derrick has been used in drilling a well 2800 ft. deep and has given entire satisfaction. The idea is new to structural design and use only can determine whether or not it is safe to depart from recognized details of construction.

The California type oil derrick shipped to South America, shown in Figs. 14 to 17, was equipped with a steel walking beam equivalent in strength to the best 12 by 26 in. white oak but had the disadvantage of requiring the use of scaffolding for its erection. The next step in the development of the steel oil derrick was to reduce the height of the panels to permit ease of erection and to construct the bull wheel, band wheel and other parts heretofore made of wood, of steel. Fig. 19 shows the latest improved form of steel drilling rig which is now a complete machine designed along well approved lines and fitted for repeated and continuous service as a machine and possessing within itself so far as consistent with stiffness and strength all the elements of simplicity and portability. The improvements incorporated in this machine as the result of observation and experience may be summarized as follows:

1° The reduction in the height of the panels to permit erection without any special equipment in the way of scaffolding and to facilitate removal of the derrick from place to place, with provision for the proper ladder to enable workmen to ascend and descend as the drilling operations may require.

2° The square construction of the bottom panel of the derrick with the elimination of buttresses and other extraneous devices for the prevention of overturning under wind stresses. The extra material which these buttresses would require has been utilized for the bull and calf wheel posts which are preferably vertical. In this type of construction the upward reactions of the drilling loads on bull and calf wheels have been modified in direction and are transmitted not into the girt by bending, but directly into the foundations by a diagonal

system of bracing which relieves the derrick itself of any upward stresses which might cause its collapse.

3° The foundation of the derrick proper is constructed of standard beams and channels so arranged as to distribute the load of the structure to concrete or masonry piers at the corner points of the derrick. The joists have been arranged with such a reference to the well hole as to be in proper position to support the string of tools, casings, etc. The sills for the machinery supports are also beams and channels so arranged as to be directly under the points of maximum loading. The knuckle posts have been arranged so as to bring the center line of the sand reel directly on the working line of the derrick, and in general the arrangement of the bracing, the foundation and the other details is such that indeterminate stresses have been entirely eliminated.

4° The bull wheel shaft is made of pipe with a special type of gudgeon threaded into its end and held in place by tap bolts. It carries a tug wheel and a brake wheel made of steel beam spokes bolted into an angle rim secured to the bull wheel shaft and carrying at their ends a bent channel rim filled with wood fillers properly grooved for the reception of the tug rope and correctly leveled for the steel band brake. These wood fillers ordinarily known as "cants," are connected to the channel rims by bolts. They can be very easily taken off and replaced when worn. The spool is made of angles framed into each other and bolted to an angle rim secured in turn to the bull wheel shaft. The wooden handles for starting the bull wheel off center are replaced by gas pipe held in position by bolts passing through the flanges of the channel rim.

5° The walking beam is built up in a tapered shape exactly similar to the wooden walking beam by the use of plates and angles. It is slotted at one end to receive the temper screw and at the other end carries a standard stirrup for the attachment of the pitman. The beam itself is supported on a column composed of two channels latticed and braced by an A-shaped structure connected with the derrick itself with provisions for the direct transmission of the load into the foundation sills. The thrusts at the bottom of the A-frame are

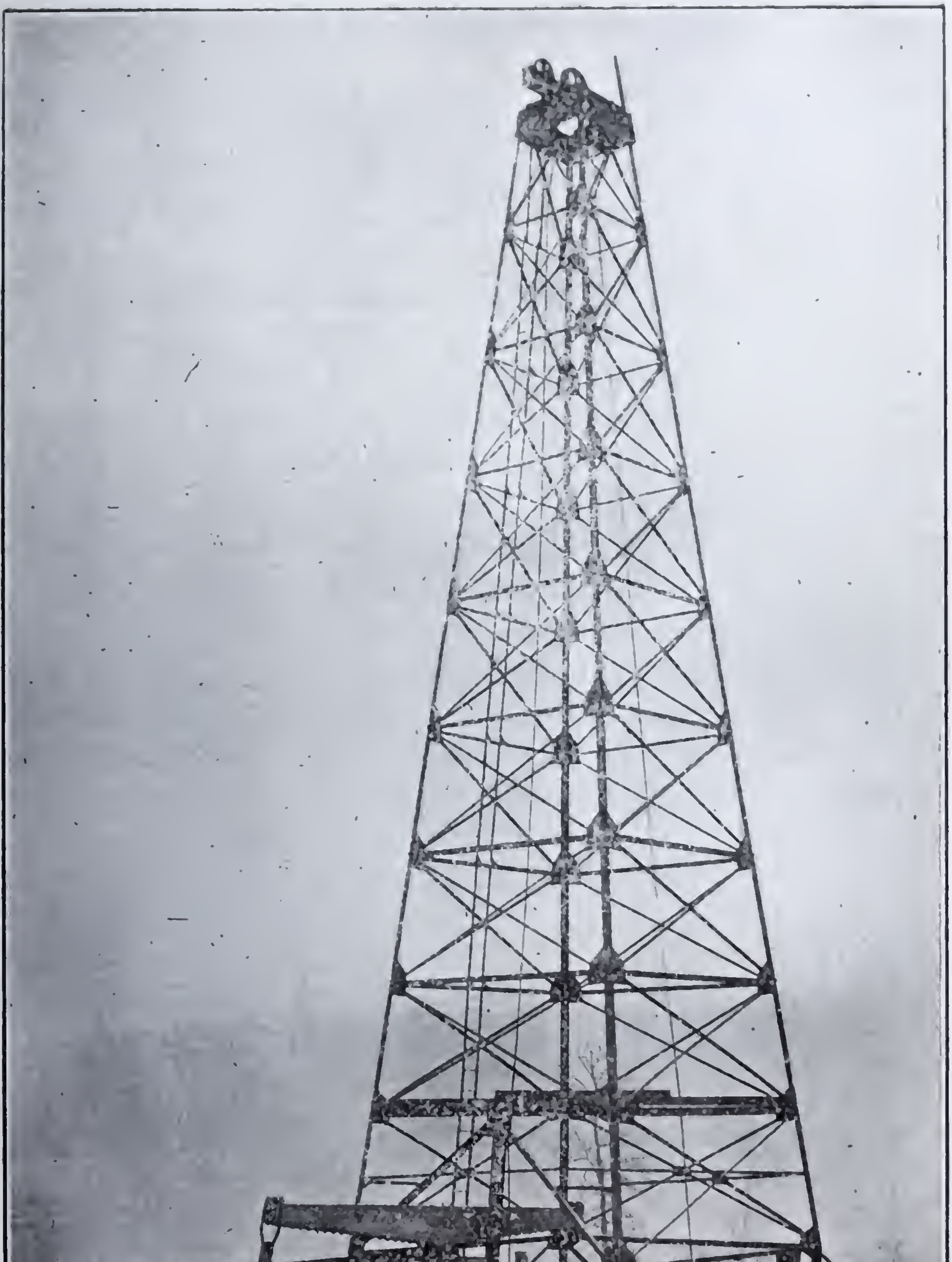


Fig. 20. 80-Foot Steel Drilling Machine, 1909 Design, Erected by Carnegie Natural Gas Company at Export, Pa.

taken care of by the channels to which they connect in the foundation, acting as ties and preventing any lateral displacement. The top of the frame is braced by angle braces to the derrick proper forming, in connection with the girt, a triangular truss.

6° The jack posts are also constructed of short latticed channel columns rigidly framed between the channels of the sills and braced against the derrick and the sand reel sills by angle braces. It will be noted that the inner jack post is also braced to the A-frame of the walking beam producing great stiffness and rigidity.

7° The inner knuckle post is framed directly to the end of the sand reel sill and stiffened by an angle and plate diaphragm riveted to the top of the main machinery support sills. The bearing for the sand reel at the top of the inner knuckle post is made adjustable to permit a movement of the sand reel an inch or two in a horizontal line to secure proper bearing of the friction pulley against the band wheel. The outer knuckle post is in two parts, the bottom of which is framed rigidly to the sand reel sill; the upper portion consists of a long channel with tapered end carrying the other bearing of the sand reel and pivoted at its connection with the lower portion by a 2 in. cotter pin. This channel forms the swing lever for the operation of the sand reel.

8° The band wheel has been constructed in a similar manner to the bull wheel by the use of steel plate flanges keyed on the standard band wheel shaft and carrying spokes to which is connected a channel rim similar to that used in the construction of the bull wheel. This channel rim is cambered about ⅜ in at its center to provide proper bearing against the friction pulley on the sand reel shaft and for the proper application of the belt. This rim has been furnished in two ways; in the one case with the back of the channel turned out where it became necessary to use an old canvas belt to obtain proper friction against the iron pulley on the sand reel shaft; in the other case the flanges of the channel have been turned out and filled with wooden cants exactly similar to those employed on the brake side of the bull wheel. The tug portion of the

band wheel is made of a smaller channel bent to a circle and connected to the spokes of the band wheel by angle and plate gussets. The flanges have been turned out and the wheel lined with wood to receive the tug.

9° The sand reel used on these derricks is the regular California double drum iron reel and in general an endeavor has been made in all instances to use standard rig irons such as are kept by dealers in oil well supplies. The crown pulleys, bull wheel bearings, temper screw and pitman bearings, saddle

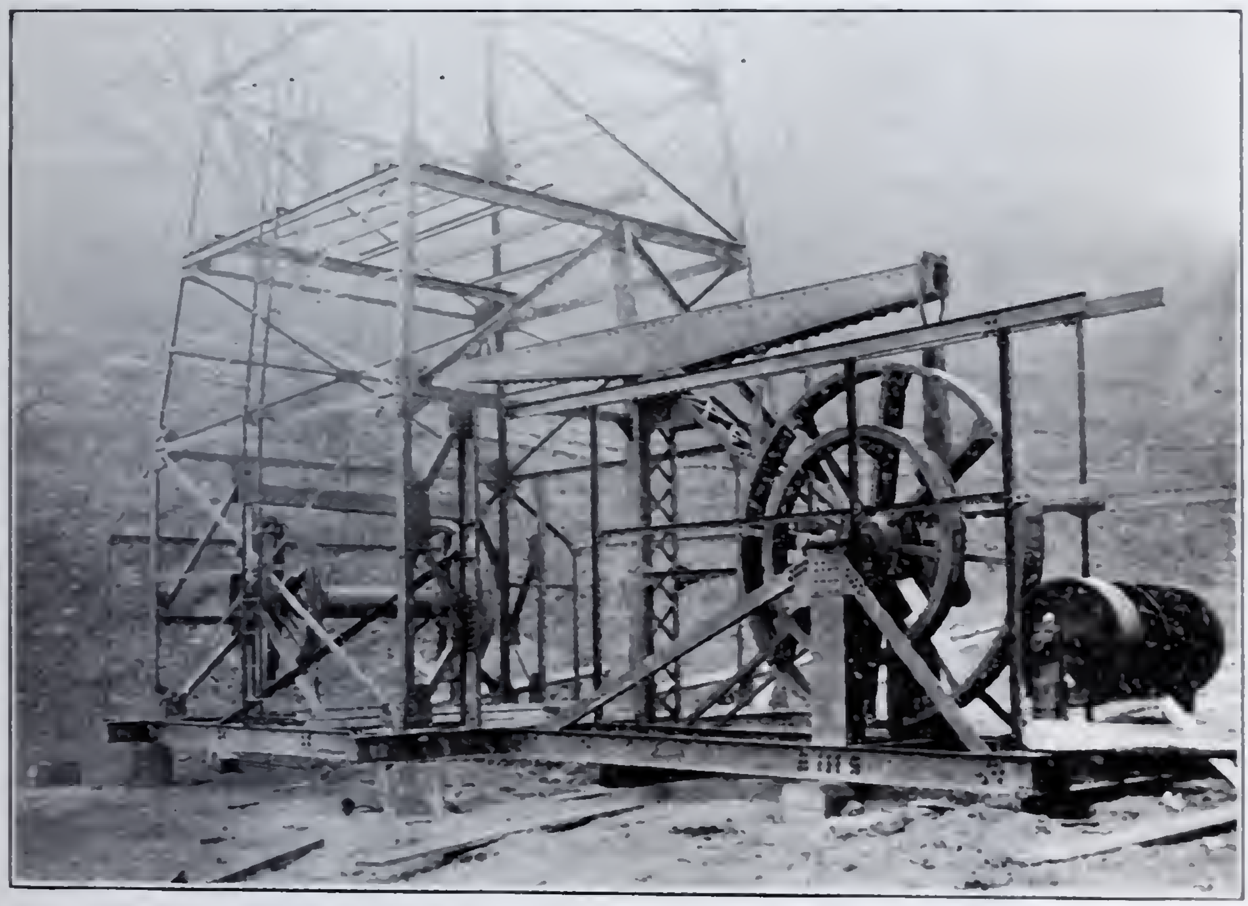


Fig. 21. Steel Drilling Machine, 1909 Design. Detail of Lower Panel

blocks, jack post bearings and sand reel bearings are of the regular standard type of construction; so also are the band wheel shaft, wrist pin and pitman.

These rigs have been employed in drilling wells 3000 ft. deep. They have been taken down and moved from place to place and have given excellent service. They possess a rigidity, stiffness and reserve strength which imparts confidence to the driller. It has been intimated that a derrick ought to possess a certain amount of elasticity and springiness. The writer

does not believe the point well taken. He looks upon a drilling rig as a machine and like a machine it ought to possess stiffness under all working conditions. In actual operations when a derrick trembles, he trembles also.

In connection with the derrick, machinery supports and drilling mechanism proper provision has also been made in the

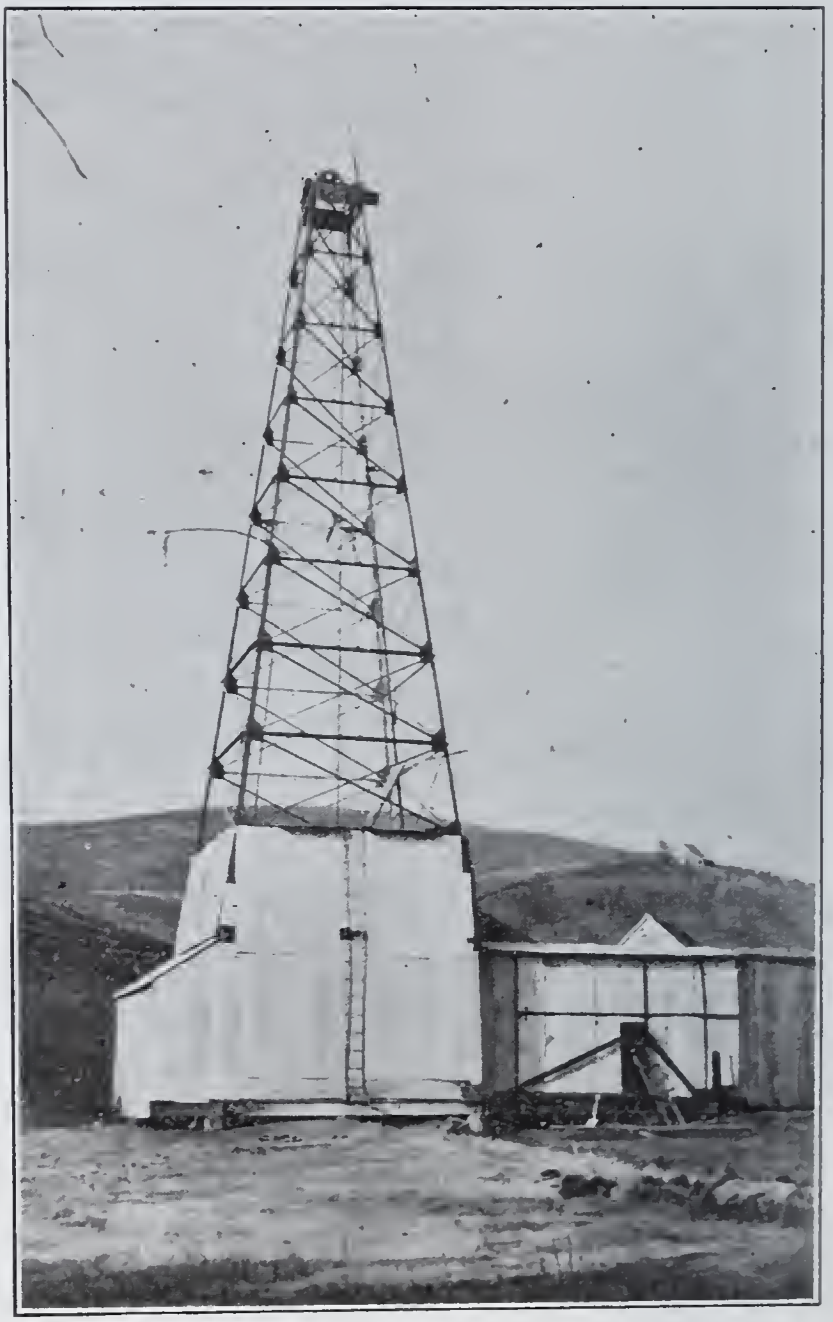


Fig. 22. Steel Drilling Machine, 1909 Design
The Completed Structure

1909 standard drilling machine for a light angle frame to take corrugated sheet covering to protect the workmen from the wind and the weather. This frame is punched for the bolting of wooden nailing strips to which the corrugated sheets are attached by roofing nails so as to be easily removable when

drilling operations are completed. The only wood employed in the construction of this drilling machine apart from that already indicated is the 2 in. planking of the derrick floor.

Fig. 20 shows the standard steel drilling rig erected complete; Fig. 21 the detail of the lower panel; Fig. 22 the finished structure with the corrugated iron house, etc.

The weight of a standard 80 foot drilling machine including derrick proper, base, ladder, walking beam, machinery supports, structural material for house, corrugated iron, bull and band wheels, crown pulleys, sand reel, etc., etc., is 57 000 lb. It is confidently believed that this drilling machine combining engineering skill with practical experience is absolutely reliable and adequate to the service it has to perform and, therefore, represents the highest type of excellence.

DISCUSSION.

Mr. L. C. Moore: I have written a brief description of a steel pipe derrick which may prove of interest.

The derrick constructed of merchant pipe for oil well and other purposes is not a new idea, there being nearly one thousand of them in service at the present time in various territories of the Eastern field of different types of construction, and the experimental stage has long since been passed. One of the first designs used screwed joints, making the legs continuous, the ends of the girts and braces being flattened and formed to fit part way around the legs, using a bolt through a drilled hole in the brace, or girt, and the leg. This construction was both cheap and fairly efficient, but not comparatively so, as has since been proven in view of the fact that, to design an outfit which would prove available for all purposes and in all locations, it is necessary that it be so arranged as to make it possible to construct it in any field shop, the only tools necessary being those usually available; viz., a common pipe cutter, a blacksmith's forge, a tape line, and either a small hand power punch or drill press.

With this object in view, the "Neill Standard Pipe Derrick" was designed. The legs are cut to exact dimensions with square ends, of convenient lengths to facilitate rapid erection

or taking down, no screwed joints or rivets being used as they are not adapted for the purpose. The sections of legs are clamped together with steel casings, shown in Fig. 23, each one not only forming a clamp but having six lugs set at right angles, which serve as points of attachment for the girts and braces, without interfering with the clamp feature. The clamps are cast slightly larger than the outside diameter of the pipe legs, thus providing a clamping fit when drawn up with the bolts. If it is desired to remove the derrick to another location, the clamp immediately releases the pipe, due to the spring of the casting, the moment the nuts are slacked off.

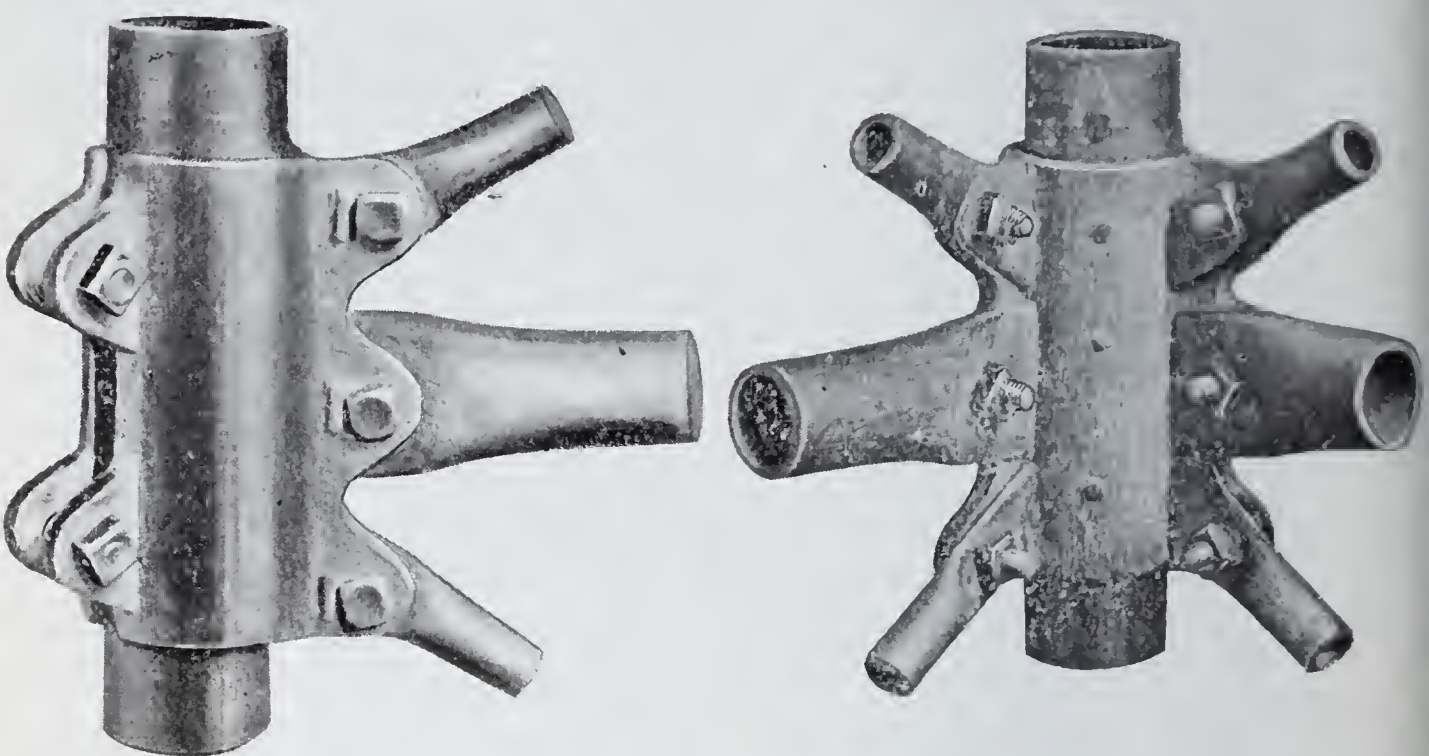


Fig. 23. Clamps

In this design no machine work is required other than that which can be accomplished with the tools referred to, excepting of course the clamp bolts and the U-bolts, used for the ladder and at the center of the cross braces, the clamps requiring no machine work. In an 80 ft. derrick, 44 clamps are required, 24 rib cored, 20 straight cored, and about 180 lb. of U-bolts. The straight cored clamps are designed for use at the center of the leg sections and are clamped in position before the sections are erected. The rib cored clamps which are used on the ends of the leg sections, have an annular rib inside at the center, against which the ends of the leg sections butt. This feature is fully appreciated in field work as the ribbed

clamp cannot slip down entirely over the pipe. In erecting, the rib cored clamps are slipped over the upper ends of the leg sections and are supported by the rib, not being clamped in position until the succeeding leg section is placed.

Fig. 24 shows an assembled derrick of this type. The legs are cut to specified lengths and this completes them. There are four of each length of girts and eight of each length of braces, which are cut to dimension, about three inches of each end being flattened with the tools at the blacksmith's fire. After being laid off and punched they are bundled in lots of four or eight as the case may be, and properly marked No. 1, No. 2, etc., after which they are ready for delivery to the location. The ladder is made of 1½ by 1½ in. angles with ¾ in. diameter steel rungs. It is 15 in. wide with rungs on 15 in. centers, and is assembled in five, 16 ft., sections. The total shop cost of fabrication does not exceed $100.00 for an 80 ft. rig of exactly the same foundation and water table, or top plan, as the standard outfits commonly known as wooden rigs.

This derrick complete, weighs less than 8000 lb., about one-third the weight of the necessary lumber for a wooden rig. As there is no cutting to waste in this design the net weight of material only, is transported to the location.

After the entire material for an 80 ft. derrick has been delivered to the location, the construction requires the services of four men, each having the ability to climb. Each man is furnished with a ratchet socket wrench and no special mechanical ability is necessary.

The derrick is designed with panels 7 ft. high to facilitate erecting and taking down. The men can reach 7 ft. to tighten nuts from the planking laid on the panel girts, which would hardly be the case if the panels were 8 ft. high, as is the case with the wooden rig.

The foundation, either of sills or concrete, having been prepared, the foundation plates are secured thereto by bolts together with the first section of pipe legs, 17 ft. long, with a straight cored clamp in position on each leg located exactly 10 ft. from the top of the foundation to center of clamp, and the first, or No. 1, girts are bolted in place. The next operation

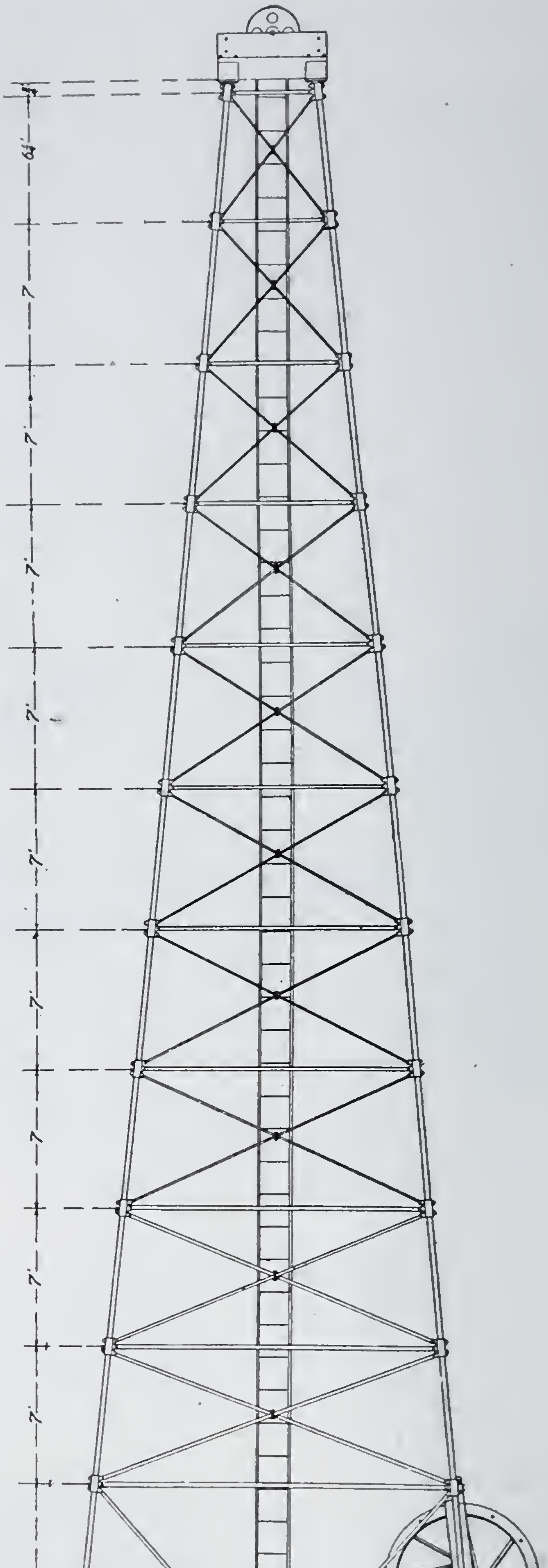


Fig. 24. Steel Pipe Oil Derrick

is the placing in position of four rib cored clamps, one on the top of each 17 ft. leg section, after which the No. 2 girts are bolted on, one man being at each corner with a ratchet socket wrench. Next the No. 1 braces are bolted up. The common railroad track bolt is used throughout the entire derrick to facilitate drawing up the nuts without the bolts turning. After erecting the first two panels, the girts and braces are secured in position, and the second leg sections, 14 ft. long, each with a straight cored clamp exactly in the center, are placed. Next the No. 3 girts and the No. 2 braces are put up and then the No. 3 rib cored clamps on top of the leg sections. The successive sections of the derrick are erected in the same manner as noted above and the time required for erecting an 80 ft. derrick of this type, 20 ft. square at the base, has never exceeded one day for four men. As there are no screwed pipe joints, all connections being clamped with bolts, the time required for taking down is even less.

One division superintendent having in use derricks of this type, with 3 in. pipe for the leg sections, 2 in. pipe for the girts and 1 in. pipe for the braces, handles strings of casing weighing, in some cases, 43 000 lb. On one occasion, having a string of 8¼ in. casing stuck at the bottom, the derrick withstood, without damage, a pull of several hours, using a three sheave, a two sheave and a single sheave block with an 11½ by 12 in. steam engine and a 25 h. p. boiler, carrying 120 lb. steam.

Mr. Patrick Yorke: It would seem that there is little to be said after Mr. Woodworth's paper. Indeed he resurrected derricks that I, as long as I have been in the business, never saw before. It is true that a wooden derrick when properly constructed is as strong as any derrick that can be erected. But its durability comes into question in several respects. That wood is susceptible to destruction through vibration and repeated stress is evinced by wood dust falling from the derrick which is caused by the wood fibers cutting each other and the working of the spikes. Then again the sun and wind warp and twist the wooden derrick so that when

taken down it is almost impossible to make a perfect structure again. Usually in West Virginia we chop the legs off and let it fall, taking it apart on the ground and making as much salvage as possible.

In the course of my work I have moved derricks to new locations, and frequently a derrick had to be torn down and reconstructed, and here I learned the many deficiencies of the wooden structure, as in every instance, whether the derrick was torn down or moved on skids, heavy expense was incurred to replace destroyed lumber and repair damages. A wooden derrick is dear, even if the driller were given the material that goes into it, free of cost. I wish to qualify this rather sweeping statement, by stating that the crookedness and general out of line condition of the second structure, built from the old one, is a continual worry to the drillers during the entire drilling of the second hole, and the frequent repairs are expensive.

Windstorms have become a factor as the timber has been cleared away and derricks undergo much more severe storms than in past years. Wooden derricks frequently blow down, often with a string of tools standing, and are liable to fall on the engine house and cause several thousands of dollars damage besides the loss of the well while replacing the derrick and making repairs.

I am strongly in favor of the structural steel derrick. When it is painted and properly put up the weather has little effect upon it; there is no question about its strength and lightning will not destroy it. If the well catches fire nothing is burned but the floor. In taking down, after one or two sections are lowered the remaining parts may be thrown to the ground unless the soil is unusually hard. This type of derrick will not fail in a wind storm; not because it is stronger, but it does not expose so much area to the wind. The top of an ordinary wooden derrick exposes about 80 sq. in. of surface to the wind, while the steel derrick exposes about a quarter of that.

Referring to the Yorke derrick, which was shown on the screen, Fig. 18, I would say that the underlying idea in this derrick, which is made of the same class and weight material as used in the derricks designed by Mr. Woodworth, is to re-

duce the number of bolts and to avoid the necessity of removing them when taking down the derrick. The ends of the bolts gather an accumulation of rust and in attempting to remove the nuts the workman is apt to twist off the bolt. The ends of the uprights or corner angles are slotted and have an 8 in. lap. The clamping bolts which secure the uprights also engage the girts and braces which are notched. In this way only four one inch bolts are used at any corner of a section in the derrick. The bolts are all put in before the material is erected and are not necessarily removed or the nuts taken off when the derrick is dismantled, it being necessary only to loosen the nuts a little to allow the various parts to draw out. The top or crown of the derrick is preferably of wood, 6 by 12 in., clamped in position by four iron rods passing through the derrick just below the crown. The wooden top is used as it is a cheaper construction and is better adapted to resist the action of salt water which will corrode iron work at the top of a derrick. A further admirable feature of the structural steel derrick is that when erected it is always straight as one angle fits into another. If the angle is straight the derrick is straight.

In my judgment the time has passed for any kind of a wooden structure. I consider my patents on wooden derricks dead stock today. Mr. Woodworth spoke of using different derricks in different districts, and the old proverb occurred to me that the good horse will do the work of poor one but the poor horse never can do the work of a good one. It is the best policy to use good rigs in shallow as well as deep territory, as the strong equipment will do better work than the light rigs. I have pulled down several derricks in pulling only 200 feet of casing which was stuck in the mud on the top of the ground, as there is very little give, if any, and the driller does not realize the strain being exerted until the top of the derrick pulls over.

Speaking of the wind element, I had a 6 in. square rigged wooden derrick in an Illinois field where 78 derricks were blown down and it was the only one left standing, not because it was stronger but it did not catch the wind as it had only

6 in. surfaces and the wind went right through it. In foreign countries where wood is scarce derricks are made of 3 in. wood doubled clear to the top.

Mr. W. W. Anderson:* I do not know that I can add anything to the discussion which we have already heard which will be of interest from an engineering standpoint, as my knowledge of the steel rig is almost entirely from the commerical side. Our company became interested in steel derricks many years ago, owing to the demands of our export customers whose operations were carried on where timber was not available. Many of our customers are operating in such distant countries that frequently the timbers sent out for wooden rigs become so badly affected by dry rot as to be entirely worthless by the time of their arrival at destination. The climatic conditions in many tropical countries practically prohibit the use of large timbers because they are so quickly destroyed, so that there are many cases even where the distance is not a factor where the steel rig is virtually required.

The first steel derricks sent out were not designed to correspond with the standard wooden rig and it was therefore necessary for the drillers to make many changes in their ordinary methods of working, so that the rigs did not meet with their approval. With the wooden rig if the parts do not go together properly an axe or saw is all that is required to remedy the trouble; with the steel rig a machine shop may be necessary, and this fact has always been one of the objections raised by the drillers.

In considering this matter we must remember that most of the drillers for oil in the various countries of the world are Americans; men who have had their first training in the oil fields of this country and who are, therefore, familiar with the wooden rig. These men object seriously to anything which is a departure from the regular outfit, which they have proved by experience to be suitable for the very severe work which is carried on in drilling a well.

About four years ago we went into the matter very

* With the Oil Well Supply Company, Pittsburgh.

thoroughly with the Carnegie Steel Company. We explained to their engineers the conditions which must be met in order to satisfy the operator, and the steel engineers made up specifications for structural material which would have suitable strength and would be in such form as to be adaptable to the peculiar work to be done.

It was not an easy matter to harmonize the various discordant features. It was at first thought by the steel engineers that it would be necessary to change some of the working parts of the rig in order to permit their use with the steel structural material. A different method was considered necessary for suspending the temper screw from the walking beam to which the tools are connected in drilling. It was also thought that the manner of attaching the pitman to the walking beam must be changed. After careful planning, however, it was decided to try the methods which have been employed for so many years with the wooden rig, adding only the necessary bearings to reduce the friction which would otherwise have resulted from the contact of iron with iron in the working parts of the rig.

It has since been proven that this arrangement was the wisest that could have been made and the steel rig has fulfilled all of the conditions which it is necessary to meet in drilling operations fully as well as the wooden rig. The steel rig has a distinct advantage in that it is possible to have a much better alignment of the various moving parts, as babbitted bearings are used, while in the wooden rig we have iron working against wood.

The complete rig which Mr. Woodworth has shown is the result of evolution and is now suited to the requirements in any oil fields of the world. When we say that the steel rig now has all of the features found in the wooden rig it is the same as saying that it has reached a state of perfection.

It was with considerable anxiety that we sent the steel rig to South America which was shown this evening. We knew that the rig was to be hauled several hundred miles from the railroad and that the man who was to have charge of the drilling operations had never seen a steel rig. The native work-

men that he would be able to obtain to assist him in erecting the rig of course knew absolutely nothing about such work, and we feared there would be considerable trouble in properly assembling the parts. The reports we received have been most gratifying. We find no trouble whatever was experienced in erecting and the illustrations which Mr. Woodworth has shown us of the moving of the rig proves conclusively that the steel rig has been of much more service to the customer than the wooden rig could possibly have been. This particular customer reports that the derrick is so strong that he could have moved it by tipping it end over end, had it not been easier to put rollers under the base and move it in that manner.

The deciding feature as to which style of rig will be used, now that the steel rig has been perfected, is the cost. The margin which is saved in using wood is becoming constantly less and the demand for the steel rig is therefore bound to constantly increase.

Mr. A. Stucki: There is no doubt that the steel rig will eventually supplant the wooden rig, just as steel has superseded wood in other fields, and as already pointed out, a great many advantages will thereby be obtained; for instance less wind resistance, no danger from fire, no splitting, shaking or pulling of nails, economy in the long run, special advantages in countries where wood is scarce and ease of erection. I would like to ask Mr. Woodworth how long it takes to erect this latest design of derrick. With the pipe design I think Mr. Moore stated that it took four men one day, and Mr. Woodworth mentioned something like three days for six men with another type of pipe derrick. I would also like to know the comparative cost.

I would especially point out that derricks made from pipe should have two advantages over those of structural steel, one on account of having the most effective section for a strut, and the other on account of offering the least resistance to the wind. Of course it is harder to connect pipes than angles, generally speaking, but Mr. Moore has certainly shown a good way to do it quickly and I think economically.

THE AUTHOR: I cannot say off hand as to the derrick proper. It takes four men three days to put up a complete drilling machine, and the complete drilling machine will cost about twice as much as a wooden machine. I am speaking of machines, not of derricks proper. A structural steel derrick ought to be put up in about a day with an ordinary gang of four men.

MR. PATRICK YORKE: At Huntington, W. Va., I put up a structural steel derrick for the Columbia Gas Company, in fourteen hours with the assistance of two carpenters and a helper, none of whom ever saw a steel derrick before. This was a derrick only, and not a drilling machine.

MR. L. C. MOORE: The first pipe derrick of the design shown in Fig. 24 that was put up, took a full day, with four roustabouts not at all skilled. They knew how to handle a wrench and that was all. With later derricks the time of erection from the foundation to the water table never has been quite a day.

The cost of a derrick of this type, not a drilling machine, built entirely of new material, is $400.

MR. C. B. ALBREE: Some twelve or fourteen years ago I took up the study of oil derricks, being asked to design a derrick by a firm who sold oil well supplies. They wanted a complete drilling machine that would be fire proof. I spent several days finding out how derricks were built and how they were used. With this data in hand I began to figure on the necessary beams and channels to hold the sampson post, the jack posts and the derrick. The derrick itself is decidedly the simple part of it. I worked two months and finally evolved something that to my inexperienced mind seemed to be just about right. But when we came to figure it up, the cost was so excessive that they would not consider it, wood at that time being much cheaper than it is now. But I got an inkling of the problems involved.

Later I was asked by the National Supply Company to figure on some derricks for export. I talked with their en-

gineers and we built quite a number of derricks which were sent out and put up. While they were not as simple as the Carnegie Steel Company's design, they efficiently did the work they were intended for.

The pipe derrick, provided it is properly designed, is in some ways more attractive than one of structural steel, because the structural steel design in many ways requires more shop work. The element of shop cost in structural steel must be considerably higher. On the other hand pipe is expensive. It is a question merely of dollars and cents as far as I can see, and the one that can be put up and taken down most quickly, and is equally strong, is the best.

ECONOMY IN CUPOLA MELTING

By J. W. Henderson.*

The mere melting of iron in a cupola is a simple operation. To get the highest efficiency out of raw materials and the necessary equipment, and convert these raw materials into metal most suitable for the work in hand, is another matter.

Although not fully realized by foundrymen in general, there is more to the cupola melting of iron and to economic production of castings from cupola metal, than the mere bringing together in a cylindrical stack lined with bricks, certain quantities of fuel and iron at varying temperatures.

Primarily the engineer is interested in the plant arrangement and equipment and their relation to economic production. As the engineers' work consists in planning the relation of the parts of the foundry to the whole scheme, with a view always to efficiency, he must be interested in all factors that assist or retard this result. In this discussion we are considering factors of economy involved in the conversion of pig iron, scrap, etc., into good castings. Examination of a large number of plants in many states, discovers some of these important factors as follows:

1° Relation of the receiving track to the ground and building plan. This is important on account of required storage room for raw materials, space for scales and narrow gauge yard tracks, and means for properly handling the charges of fuel and iron.

2° Weighing facilities that will require careful weighing of each complete charge as a separate unit. This is a sadly neglected part of the equipment in most foundries. A few of the general practices will be mentioned later.

3° The elevator should be placed, in relation to the position of the cupola, so that the maximum loads of fuel and

* Foundry Specialist, Gulick, Henderson & Co.

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iron charges can be handled with the least interference with the operations on the charging floor.

4° The charging room capacity in smaller foundries should be sufficient to carry the charges for the total heat, and in larger foundries adjusted so that the immediate cupola laborers will need the minimum assistance.

5° Cupola details. Those of importance are:

- Extension of the spout into the foundry.
- Height of spout above foundry floor.
- Depth of cupola from sand bottom to charging door.
- Dimensions of charging doors and the distance between the doors and the charging room floor.
- Capacity of the cupola, when lined to its largest inside diameter with safety, always in advance of shop requirements, and with blower or fan capacity and adjustment within a range that will permit the melting speed to be as elastic as the needs of the shop might demand.

These engineering details of plant arrangement and equipment not only influence economies but they also assist or hinder systematic operations and accuracy.

Many years experience convinces that those engaged in chilled iron work, such as cast iron car wheels, and those making malleable iron from the cupola are to be credited with most of the present development of cupola practice in this country. This has not been on account of their greater intelligence, necessarily, but rather a matter of compulsion. For example consider car wheel iron. When the metal is running close to the lowest limit as to chilling qualities, if the silicon content increases .05 percent the chill on the wheels will drop below the specification limits, and the wheels made therefrom will be bad so far as their acceptance by the railroads is concerned. If one such wheel among a lot of a hundred, is found by the inspector, he will reject the whole lot even though the other ninety and nine might be known to be all right in every way.

Cupola melting of iron is simple until you give personal attention to the actual running of a cupola and try to produce accurate results as to temperature, composition, chill, strength,

shrinkage, etc., in any given kind of castings. Some varied experiments may be of interest.

Cupola *A*. Sand bottom to charging door, 17 ft; diameter straight lining, 45 in.; diameter of melting zone, 38 in. Cupola started with 1500 lb. bed coke for 1500 lb. first iron charge. This was varied to 1800 lb. bed coke and 2000 lb. first iron charge but good, very hot, iron was not obtained under good control until the bed coke was made 2000 lb. and the first iron charge increased to more than double this or 4400 lb. Afterwards it was common practice to take out of this cupola at each heat, four different mixtures varying in silicon from .75 percent to 2.50 percent. Although no extra coke was used to divide them, the four mixtures were produced each day, with the desired differences in composition and separated from each other.

Cupola *B*. Diameter varied from 48 in. to 69 in. and depth from charging door to sand bottom was 9 ft. 6 in. Weight of pig iron was taken by considering an average weight for the pigs and making up the charges by counting them. Weight of the scrap was left entirely to the guess of the head charger. Charges were supposed to be 4500 lb. each and were so shown on the records, but on checking up the work being done, and allowing 50 lb. as the average load carried each trip of the men from the scrap pile to the cupola, it was found that the charges would vary from 3500 lb. to 4200 lb. The coke was forked into the cupola until it reached a measured distance from the charging door. At 25 lb. per fork found that the total bed coke would amount to 3400 lb. After taking up melting on the chemical basis these conditions were changed.

Cupola *C*. Making very thin and small special castings requiring very hot iron of uniform composition. Cupola was 50 in. diameter and 14 ft. in depth. Coke and iron charged in barrows. At one time they found the average barrow load of coke to weigh 120 lb., so this was still being used to determine quantities charged. When on hand to check up the actual conditions was told by the man in charge that the bed coke each day consisted of 1800 lb., made up from 15 wheel barrow

loads. Weighing all barrow loads discovered that the total bed actually weighed 2600 ℔. Upon this was put iron charge of 2500 ℔. Single charges of coke varied throughout the heat from 3½ to 5 barrow loads. The product varied in quality with the "luck" which they had in striking the right conditions. Today this shop is securing very hot iron of uniform quality continuously.

Cupola *D*. Making special chilled work. Melting rate was too slow for the enlarged shop. Cupola 58 in. diameter. With single charges of 4000 ℔. each the output was 8.5 tons per hour. Increasing the charges of coke and iron, but reducing the then coke charge gave a melting rate of 9.5 tons obtained per hour. Thus hotter iron of more uniform composition was obtained, at an increased rate of 1 ton more per hour. The best results were obtained with the iron charges amounting to 7000 ℔. each. It will be well to say here that the character of the raw materials, the diameter of the cupola, and means for mixing the iron after it is melted, must be considered in determining the size and weight of the iron charges.

Referring again to conditions similar to cupola *B* given above, I will state that where any attempt is made to make up the charges by weight the proceeding is usually somewhat as follows: Scrap, and the iron by brands, are taken up an incline in wheel barrows, and piled in the charging room. From these the charges are made up piece meal on a scale too small to hold a complete charge, and the assembled charge is again piled on the charging room floor. Once more this metal is handled and thrown into the cupola through a door that is above the waist line of the men. Altogether the metal composing the charge is handled five times at least.

The coke is also taken into the charging room by barrows and from the piles thus formed is charged by wire, or solid metal basket, or by fork. It is a common thing to find records being kept that show 45 ℔. as the basket load when 40 ℔. is correct, or vice versa, and 18 ℔. to the fork when 25 ℔. should be the weight shown.

The blower and the fan. Here is the case of a shop melting 400 tons per day. The shop had been increased so that

the requirements were beyond the capacity of the power plant, and it was necessary to enlarge the latter or conserve energy at some point. The No. 10 fan was thrown out and a blower put in its place with the result of saving 35 h. p. and still being capable of doing more than was being accomplished with the fan. There is another case of a continuous shop driving fans to their fullest capacity, and having considerable trouble to keep belts on them. Here the blower saved over 30 h. p. besides removing all belt troubles.

There are five distinct outlines of cupola linings shown in the accompanying illustrations. Eliminating the straight and the burned out linings as shown in Figs. 1 and 2, if I were asked which of the remaining three is the best, I would not

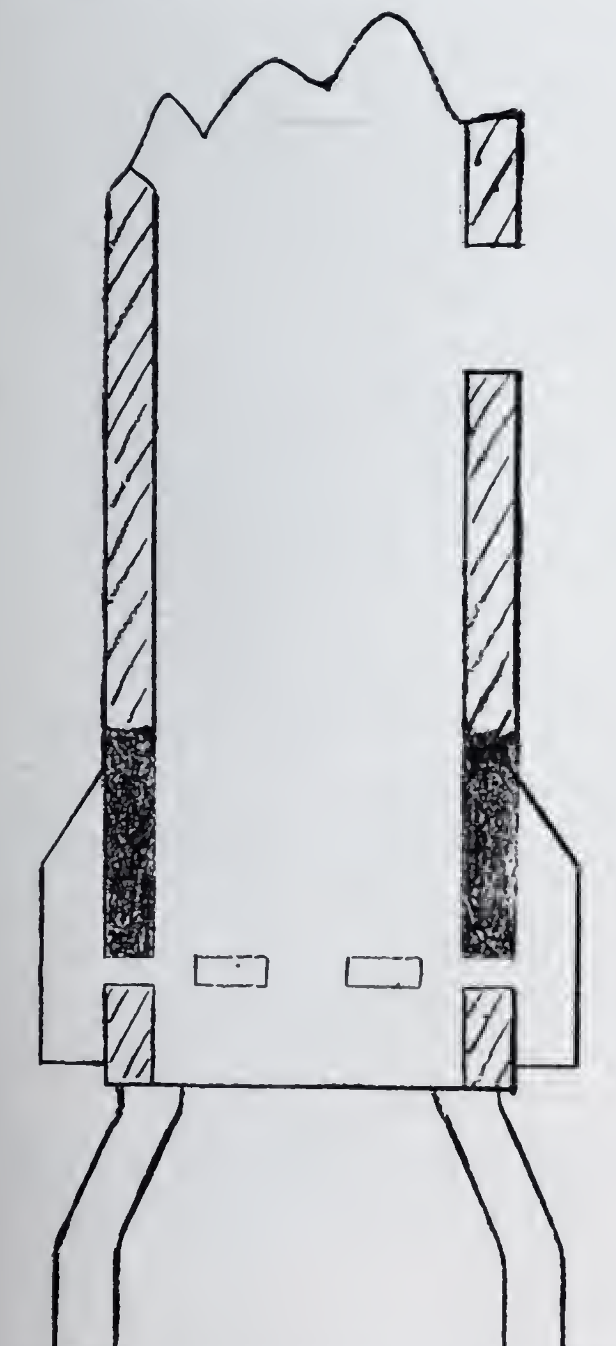

Fig. 1

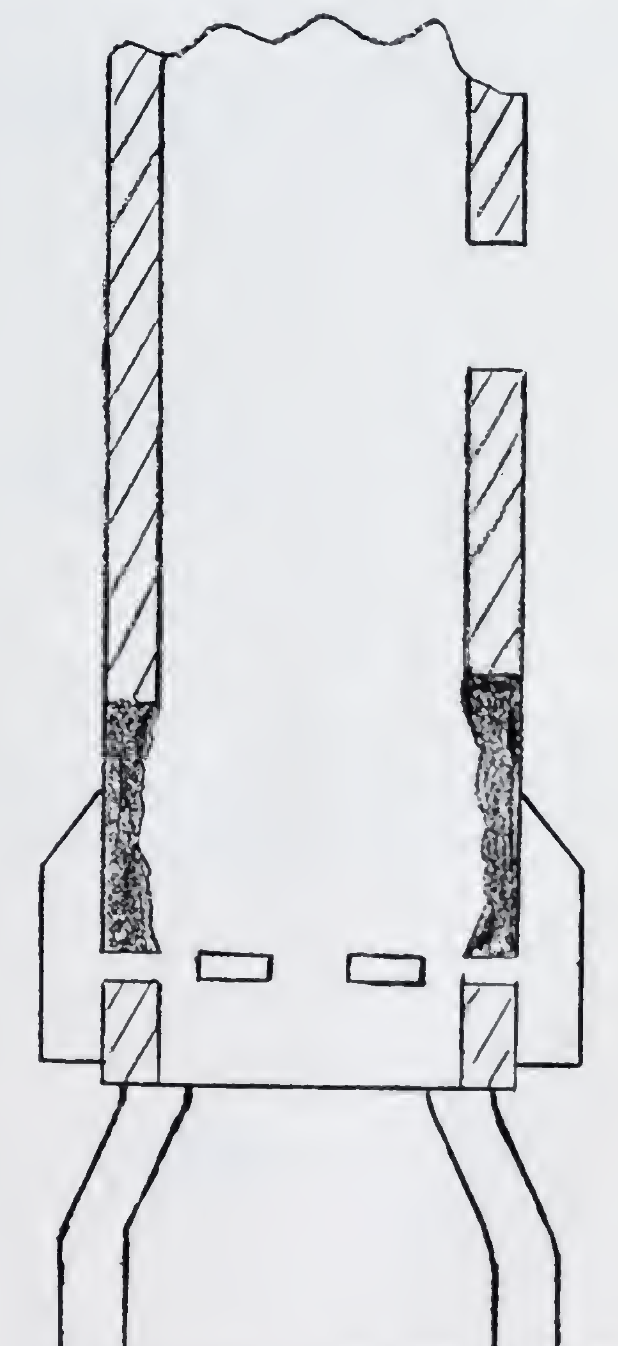

Fig. 2

give a direct answer. Each of them is good under certain conditions.

That shown in Fig. 3 will be found the most serviceable generally. It is quite important where the point of the bulge is placed. If properly used this bulge will prevent the bunging up of the tuyeres, daily patching of the lining, and will aid the temperature without materially reducing the melting rate.

The arrangement shown in Fig. 4 permits carrying a very thin lining above the bulge. It is also possible with this lining to carry iron bricks in the lining for several rows below the charging door. With this bulge and the thinner lining above it the cubic capacity can be increased, the quantity of bed coke decreased, while reducing lining repairs and increasing the temperature of the metal. However, with this bulge the charges cannot be melted in their regular order.

The outline shown in Fig. 5 is the best for obtaining uniform temperature, oxidation and melting. The dimensions should be maintained within one-half inch variation each day. This requires patching before each heat. There is no question but that the gain in quality of product is worth the trouble and expense. Only with this style of lining, can accurate melting points be discovered after each heat, that will indicate just how regular the charging has been done. Except for very long heats the melting point can be established by the method of burning the bed coke.

There are of course many modifications of these outlines. As a rule too little attention is paid to the cupola lining and its effect upon temperature and the melting rate.

To accomplish the best results, the mixing by chemical analysis is not merely the province of a chemist. As a matter of fact, where the chemist is only a chemist and not a foundryman, and no one else in the shop is acquainted with chemistry or metallurgy, the chances for definite improvement are doubtful.

This will account for the sad experiences of some few of the foundrymen in this district. There is in mind one proprietor in particular who claims that the entry of a chemist into his foundry cost him $10 000. Where the chemist who is

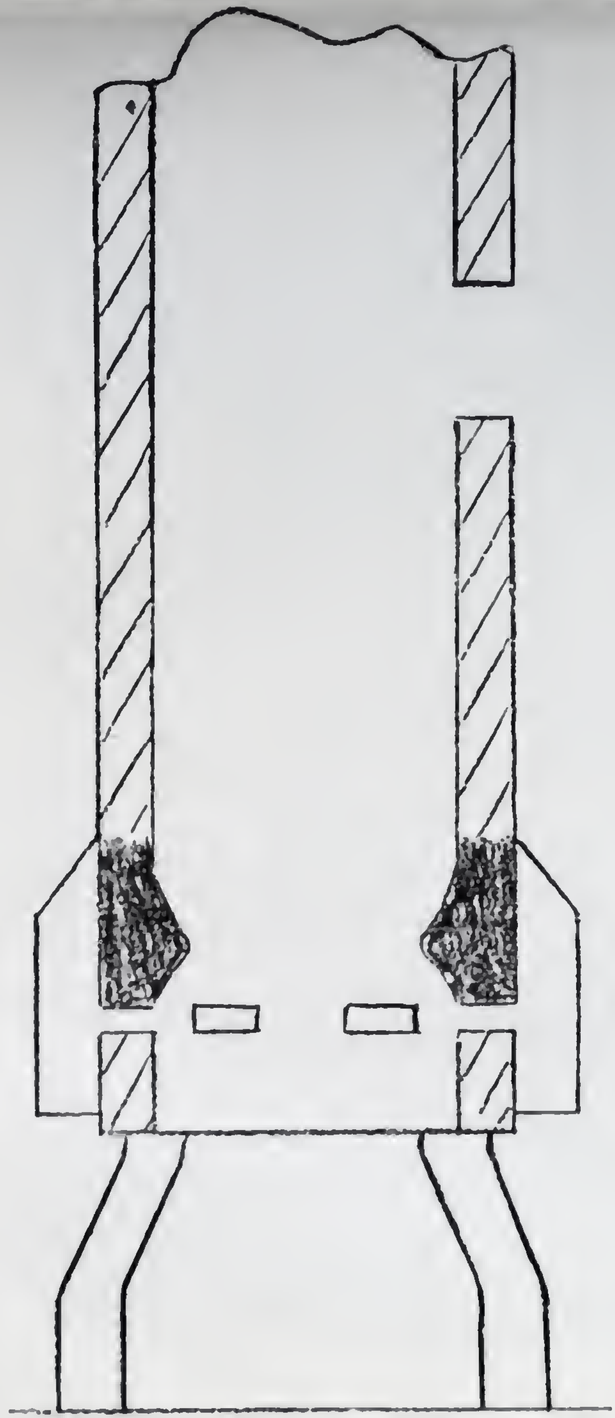

Fig. 3

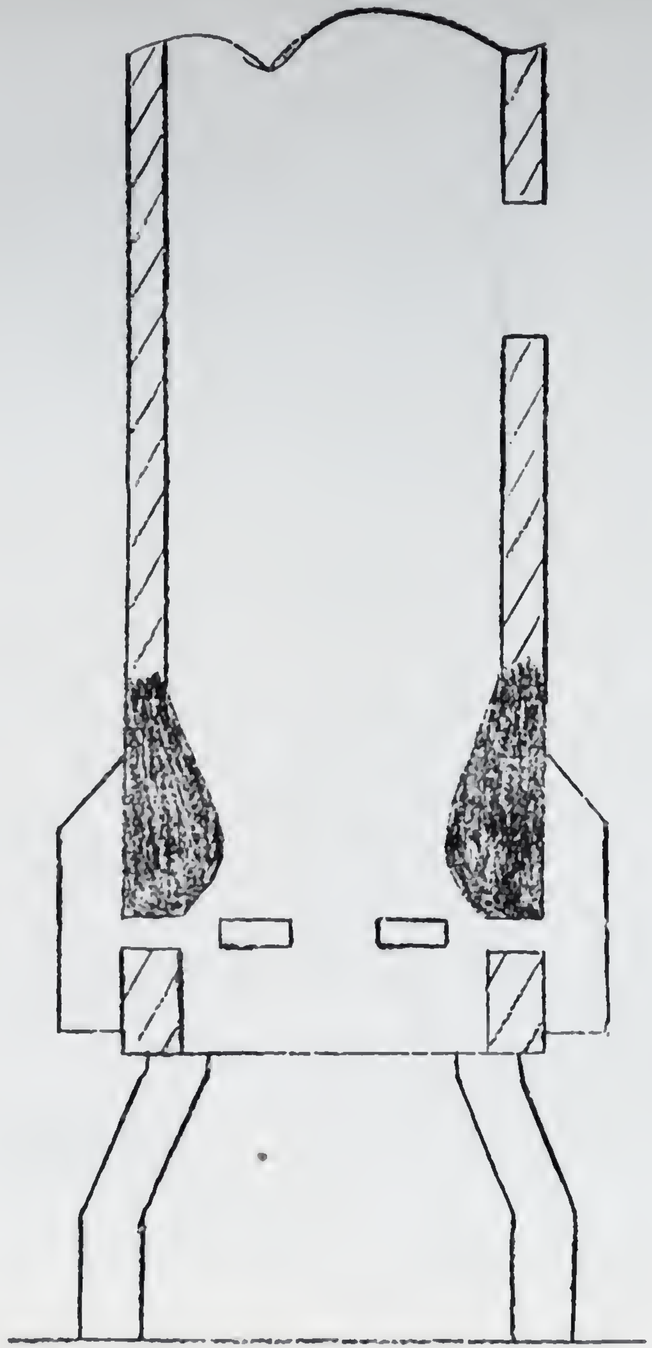

Fig. 4

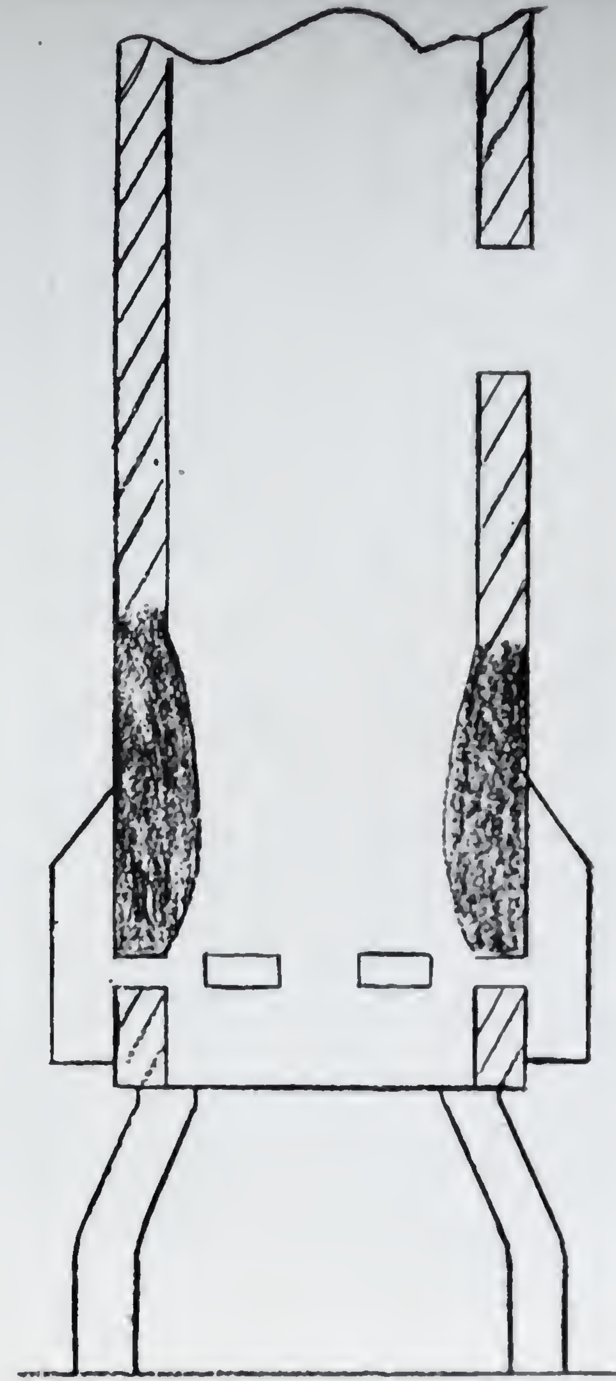

Fig. 5

also an experienced foundryman, has not the co-operation and assistance of the officials and those in direct charge of the cupola and foundry, the results from mixing by chemical analysis will be negative. The chemistry part of it bears about the same relation to the results that the bookkeeping in the establishment bears to the profits at the end of the year.

Again, the chemical analysis of the materials may be perfect, and the weighing of the charges may be accurate, yet the resulting metal from the cupola may be made almost worthless in the operation of melting. Or if these things are carried on as they should be, still the castings may be bad from the way the metal is handled and poured, and in special cases in the manner of cooling or shaking out, or in the annealing of the castings.

To the practical chemist and metallurgist the "brands" of iron, as brands, mean nothing except as the name stands for composition and structure. Notwithstanding demonstrated facts which disprove the following claims, it is not an uncommon thing to hear foundrymen express themselves as follows: "Don't the steel go into the sand bottom?" "Don't stove plate go up the stack or out with slag?" "We have to have charcoal iron in our castings in order to get the chill and strength." "Nothing will close up the grain in cylinder castings like old car wheels." And so it goes with the foundrymen visiting conventions, listening to and reading the educational papers, still clinging to the ways of the past century. It does not make any difference what kind of castings you are making you cannot today get away from the benefits derived from chemistry and metallurgy, and generally better castings at lower cost will be made by employing these in your foundry. Blast furnace practice is not what it was twenty years ago. In those days if the silicon percentage dropped a given number of points the chemist on the particular furnace output, could know that there would be an increase in the sulphur content and almost what the percentage would be. A few years later the same blast furnaces were making low silicon iron contain-

ing lower sulphur than was thought possible from coke iron furnaces.

Whether making stove plate or ordinary machine castings, automobile cylinders, semi-steel castings, or any other kind, after once determining the composition and at what temperature the best of these has been made, the desire should be to duplicate them continuously. You cannot be confident of duplicating castings day in and day out, and take advantage of the market changes in iron and fuel, without chemistry and metallurgy.

Here is the analysis of six pigs taken from the same car load of a well known brand of iron. Silicon, .87, .99, 1.62, 1.70, 1.79 and 1.82 percent. Chemistry obtained a rebate on this iron, enabled the foundry to use it without loss of castings and prevented future shipments of such mixed iron from the same source to this foundry. Without chemistry the resulting bad castings would have been charged to the coke first, and if that was found not guilty then to anything but this particular brand of iron which had been used theretofore without loss of castings attributable to it.

Knowing these things and that there are frequently even greater variations in analysis between different car loads of the same brand of iron, it is not difficult to realize the lack of uniformity in the castings produced where several hundred car loads of iron are thrown together in one pile. When a number of such piles are found on the property of concerns (generally favorable to scientific methods) the marvel increases.

To be successful, mixing by chemical analysis must be supplementary to that experience which is familiar with general cupola practice and the effect on the results desired, of every operation from the raw materials to the loading of the finished castings for shipment. Given the chemical analysis and applying the personal attention, many foundrymen might work out the results themselves. System in the laboratory has brought the cost of analysis within the reach of even the smallest foundry.

As indicating what is being accomplished, attention is called to the analysis of test pieces from three plants in different parts of the country.

Test piece	Silicon	Manganese	Sulphur	Phosphorus	Combined Carbon
		Foundry No. 1			
No. 1	2.39	.57	.088	.632	
No. 2	2.36	.58	.076	.612	
	Same plant, same kind of castings one year later.				
No. 1	2.25	.53	.074	.636	
No. 2	2.23	.50	.064	.632	
		Foundry No. 2			
No. 1	.55	.53			.61
No. 2	.52	.57			.59
No. 3	.54	.51			.60
	Same plant, same chilled work several months later				
No. 1	.49	.57			.60
No. 2	.55	.64			.54
No. 3	.55	.49			.58
		Foundry No. 3			
No. 1	2.54	.46	.070	.720	
No. 2	2.44	.49	.080	.690	
	Same plant, same kind castings one year later				
No. 1	2.42	.51	.067	.778	
No. 2	2.32	.49	.074	.780	

While maintaining this uniformity the castings are being produced at lower mixture cost than before and the casting losses chargeable to the metal are reduced to a minimum. One more point is that of a company which at the beginning of the financial depression, found itself with several hundred tons of iron on hand not suitable for the castings to be made. Business policy dictated buying as little iron as possible at that time and this was accomplished by the chemical analysis indicating just what the minimum amount of iron would have to be composed of to dilute the elements which were too high and what to make up for those elements which were too low, in the stock already on hand.

Advancement in any branch of the iron industry moves in two lines generally parallel to each other though often converging, the one scientific and the other practical. With

cupola melting considered so simple that any man with a few hundred dollars can engage in the business with hope of reward, and with cupola practice in the chaotic condition in which we find it today in even many of the large foundries, advancement in economical melting along either scientific or practical lines needs necessity to give it movement.

Fundamentally, the small manufacturer cannot take advantage of, and the large one will not introduce, the latest methods affecting economies or a higher standard, worked out by the application of science to practical purposes.

Neither will concede the time to give the application of new methods the personal attention they require and deserve. Foundrymen will run after some new improvement in cupola design, or the suggestions for changes in the size and weight of the iron and fuel charges, when the same amount of time and personal attention given to the devices and materials they now have would yield large returns in economies to be added to the profits at the end of the year. Ask nine superintendents out of every ten the following questions and see if any of them can promptly answer them correctly:

1° What are the inside dimensions of your cupola?

2° What are the inside dimensions of your tuyeres?

3° What is the actual ratio of coke to iron of the bed charge?

4° What is the actual ratio of coke to iron of the other charges?

There is in mind a man 75 years of age whose story is a lesson and an example. After stating that he started in the foundry business in 1870 he was asked, " Well I suppose you have made yourself rich from it in the mean time?" His answer was, " No, I'm poorer than when I began."

We have had combinations in seemingly all lines except that of the grey iron foundry business. It would seem that here is an opportunity on account of the possibilities for economies in all departments, but particularly that of cupola melting. We are never dealing with ultimates. Advancement lies in getting the most of the so-called elements that are in the raw materials at hand in any given locality. Europe has

been compelled to be in advance of us in cupola practice. We will find that better malleable can be made in the cupola than has been the experience in the past, and that grey iron in all its branches, including what is called semi-steel, can be produced within definite and somewhat narrow limits as to tensile and transverse strength, chill, wear, deflection, etc. It is an easy matter today to make grey iron with tensile strength 24 000 lb. to 30 000 lb. and semi-steel with tensile strength 36-000 lb. to 42 000 lb. per square inch. There is an unconfirmed report of an eastern concern producing semi-steel with tensile strength in ordinary test bars over 48 000 lb. The likelihood is that competition, and combinations of capital, and increased cost of raw materials, will do more towards economies in this branch of founding than all the inherent intelligence or present standards for excellence.

DISCUSSION

MR. W. A. BOLE:* I regret very much that I was not able to get here in time to hear the paper, as I wanted very much to hear from someone who knows. I judge from the sketches on the blackboard that Mr. Henderson has been describing different forms of cupolas. I might say that it is not a world wide custom to construct cupolas just as those are. Nearly all the cupolas used in European foundries are different from these, which might be called the American type of cupola. The European type of cupola is almost invariably built without any reservoir capacity for holding the molten metal within the cupola and the tuyeres are low, near the bottom. As fast as the iron melts it runs out into a fire brick reservoir, or "fore hearth," which is roofed over and protected from radiation. When I first saw that kind of a cupola it looked somewhat cumberous, but I have latterly come to the conclusion that there is a good deal of justification for its persistance on the other side. We have to go to France and Germany for a great many of our best ideas in metallurgical matters as you know. We do not any of us know exactly what

* Consulting Engineer, The Westinghouse Machine Co.

happens inside a cupola, but we can do some guessing. The presumption is that the coke which is put in the preliminary charge below the tuyeres does not burn because no air gets at it, or practically none. In the style of cupola in vogue here it seems to me that it is bad to have the molten metal lie in the cupola for quite a length of time, accumulating until it can be tapped out, all this time surrounding and submerging the coke and very likely taking up a considerable amount of the sulphur content of the coke. The practice on the other side is to have the tuyeres very low and let the metal get away from the coke as fast as it melts and can run out into the fore hearth.

No longer ago than yesterday I was discussing foundry matters with the foreman of a large railway shop in Virginia and I called his attention to this European cupola construction. He said it recalled to his mind an experience that he had never been able to explain. He had at one time been foreman in a stove foundry where they tapped the metal as fast as it was melted. After that he was employed in a neighboring foundry where they were making miscellaneous castings, using the same irons as when he was in the stove business, and he was disappointed to find that his castings were uniformly harder than they had been when he was melting the same iron in stove work. That cupola construction seemed to strike him as being an explanation of the behavior of that metal. In the stove foundry the metal was taken away as fast as it melted and in the other it was held in the cupola surrounded by the coke which would give up some of its sulphur to the iron.

I judge from the figures on the blackboard that Mr. Henderson has also been talking about the chemical composition, and from previous conversations with him I judge that he believes there is a lot blamed on the sulphur content that it does not always deserve. My own notion is that for certain purposes and certain kinds of castings sulphur is more or less desirable, and you cannot get just what you want without it. Probably he will agree with the proposition that for small castings the less sulphur the better; but for large and heavy castings it is not possible to get good high strength without

reasonably high sulphur content. You can get a lot of bad castings that are not traceable to the cupola or the iron, but either to misbehavior on the part of the melters, or in the method of putting the iron into the molds or bad gating, or a lot of things like that; but in case of doubt "Sulphur" is a familiar scape goat.

Mr. C. S. Koch:* We melt about 40 percent steel in our cupola. It is about 36 in. inside diameter. What distance should our charging doors be above the tuyeres? Of course I understand the higher the better, but what should be the minimum? We only melt about 7 tons an hour and run about 5 hours.

The Author: I know of one case where they have two charging doors. The first is about 14 ft. from the bottom. That is a good economical depth. They charge the cupola up to that door, then close it and go up to the upper door about 10 ft. higher and charge the balance of the heat. But 14 ft. is a good depth.

Mr. C. S. Koch: Would we gain much if we raised it say 4 ft?

The Author: You would gain something in coke saving or in temperature.

In regard to what Mr. Bole said about the gentleman in Virginia, if he charged by grades only and not by chemical analysis I would say that his testimony was not worth anything. At the same time where you do increase the sulphur by holding the iron in the bed you also increase the total carbon, which means retaining the heat, perhaps offsetting the sulphur. Of course it depends on the section of the casting at that. The carbon is also affected by the blast pressure. I know of one experience where we were running 3.5 percent carbon and increased it to 3.8 percent in the same cupola on the same charges.

Mr. W. A. Bole: What pressure of blast would you recommend?

* Manager, Fort Pitt Steel Casting Co.

The Author: Twelve oz. pressure would be sufficient, although if you are trying to make malleable and are endeavoring to burn out the carbon and melting very hot iron 16, 18 or 20 oz. would be best. Ordinarily with gray iron castings 12 oz. is enough.

Mr. C. S. Koch: About tapping out immediately, I was raised in the radiator business and learned that it was necessary to have the iron run right out the same as stove plate. In fact the foreman had that impressed on him thoroughly, and if there was any delay in pouring and they had to stop he knew that the next day the machine shop on thin section radiators would be after him. We proved conclusively that the sulphur was raised considerably. So we arranged that if there was any delay in drawing off the iron it was thrown in the ladle.

A Member: I would like to ask if any attempt has been made to use electric melting in foundry practice.

Mr. W. A. Bole: None that I know of.

The Author: That is along the line I spoke of about the foundrymen running after new devices. If they worked out what they have they would not need it. They have no electric devices simple enough as yet to do it at low enough cost. In the Heroult process the U. S. Steel Corporation is introducing re-melting. I understand they take the metal from the Bessemer converter and put it in this furnace, not taking it directly from the ore or from the pig iron either.

Mr. W. A. Bole: I would like to ask Mr. Henderson his views concerning the best way to divide up charges, whether a big charge of iron and a big charge of coke, or small charges of each. I believe Dr. Moldenke has been preaching the gospel of thin slices, not changing the ratio however of iron to coke.

The Author: As I understand it Dr. Moldenke's theory is that with large charges you increase the oxidization and the oxide of iron goes out of the charge. Theoretically that may

be all right but practically it does not work out. In the case I cited the cupola was melting too slow for the shop on account of their having increased their capacity. They were running a 58 in. cupola with 4000 lb. charge. We increased the charge to 7000 lb. Instead of multiplying the coke charge proportionally we reduced it and got hotter iron and more uniform and increased melting.

Mr. W. A. Bole: What is a good ratio between coke and iron with charges subsequent to the bed charge?

The Author: It depends on the work. With stove plate and thin plate work of that sort, 1 to 8, or 1 to 9; but on car wheel work or ordinary gray iron castings, if it is followed very carefully there is no reason why you cannot get 1 to 10. I have known 1 to 12 but that was under very exceptional circumstances. In one case only we have accomplished a melting ratio of 1 to 5 in the bed. Ordinarily 1 to 2½, or 3½, is a very good result.

Mr. W. A. Bole: Do you know anything about fluxes that will hold back some of the sulphur in slag, or keep it from entering the molten iron?

The Author: I have never seen it accomplished. As you said a while ago, I am sure that all sulphur is not bad. If I want strong iron, even though there is considerable silicon in the iron, I will increase the sulphur and will get strength.

Mr. W. A. Bole: Perhaps nobody here resorts to the practice of melting the iron twice, because that costs too much. But if you broke the iron up and charged it into the cupola again the various fragments would be placed in new positions with respect to each other and you would get greater homogeneity. If some one could get up a simple process of giving molten metal a good stirring I think we would get better results. There is a sort of coffee and cream effect, and we do not get a perfectly homogeneous mass in the ladles. There is quite a stratification of different iron in it. If we could have a big spoon and stir the iron vigorously in the ladle after it is tapped I believe we would get benefit, just as we stir the

coffee and the cream before we drink it. Do you know any one who is doing that?

The Author: No, I do not.

Mr. C. B. Albree: Among some moving pictures the other night I saw one of an iron works in England, showing the pouring of iron castings, and I noticed that when the ladle was ready to pour the workman in charge thoroughly stirred it just before pouring, so that would seem to be the English practice.

The Author: He would lose in temperature all he would gain in the mixing.

Mr. W. A. Bole: I do not know any foundrymen in the world who quite equal some of the Swiss engine builders. I have noticed in their iron and steel mixtures they do not attempt to charge the steel scrap into the cupola for the same heat in which the castings belong. They charge the steel scrap with the residual iron the day before and pour the mixture into the pig bed. They then break those pigs up into pieces not over 6 in. or 8 in. long, and remelt. They get a homogeneity thereby that comes pretty near being all that could be desired. What I mean is that pigs in any car lot are not all alike. One of the great difficulties in forming any conclusions about foundry practice is that we reason from specific samples and there is no way to tell whether the samples actually represent the mass. And there are instances of two castings out of the same ladle, one of them hard and the other soft, indicating stratification. Possibly some of this may be purely mechanical. Anything that helps to insure homogeneity is bound to be good.

The Author: I spoke in the paper of one car varying from .87 to 1.82 percent silicon. But if the methods of taking samples are systematized as they should be, it is a very easy matter to tell whether a car is mixed iron or not, and if it is, it is a simple matter to use it in such quantities that the difference in silicon from normal will not affect the whole mass.

Mr. C. S. Koch: We made some experiments similar to that. We converted our iron into steel first, probably 10

percent carbon, I do not know how the sulphur or phosphorus stood, and for some castings we wanted a higher carbon and we poured into the ladle some molten iron raising the carbon. When we started to do that some thought that the iron we poured out of that 2-ton ladle would be harder at the top than at the bottom, so we took eight tests and the carbon was always up in the air in the analysis, showing that the carbon had fairly well disseminated through the ladle. Of course there was a chemical action when we poured out the iron, a bubbling, but not very intense. We found that the carbon was the same all through, within the errors of analysis.

MR. W. A. BOLE: I do not know whether the other elements would be as likely to diffuse themselves as the carbon.

THE AUTHOR: If the phosphorus were very high it might tend to segregate, and the sulphur also. I doubt if you would find much difference in the silicon unless you cooled it slowly and had a heavy section.

MR. W. A. BOLE: I learned to my surprise in Detroit a month ago that the foundrymen there put a premium on Solvay coke for foundry purposes. I had supposed Connellsville coke was standard the world over. They say it makes excellent automobile castings and when they want hard castings they deliberately use Connellsville coke to raise the sulphur and thus increase the hardening of the metal. They claim Solvay coke has ½ to $\frac{6}{10}$ percent of sulphur, and we think we are doing pretty well to get below 1 percent when using Connellsville coke.

THE AUTHOR: We do not get Solvey coke in this part of the country. In New York state I had a little experience with it and the best I could get was 1 to 6, and the company was instructed that if they could get any one of a number of very hard Connellsville cokes they would obtain a melting ratio of 1 to 10, which they did. I understand that in the early days of Solvey coke it was very unreliable. At first you would get good coke with high melting ratio, but after that it would average irregular.

MR. C. S. KOCH: I can confirm what Mr. Bole says. I

was with a company in 1900 that started with Solvay coke. The head office would tell absolutely no one where we got our coke. We thought the supply was limited. We were getting good results and it was something like 20c a ton cheaper and it was delivered almost as far from Detroit as Pittsburgh. We ran very light castings and all the iron was carried in small hand ladles, about 40 lb.

MR. W. A. BOLE: What is your opinion as to the necessity for using charcoal iron to make good car wheels?

THE AUTHOR: It is not necessary in any castings to make good ones. And please notice that I emphasize the "any." I make this statement, and I have made it here before. It does not make any difference where you get the elements from, if you duplicate them under the same heat treatment, with all the foundry conditions the same, you get the same result. I made that statement before the chemist and consulting engineer of one of the largest railroad systems, one that is held up to all railroads as being the standard, and I found that he agreed with me. And it is peculiar that that company is using charcoal iron.

MR. W. A. BOLE: We are unfortunate in not being able to comprehend all the chemical processes which may take place in melting metals; but one thing I think I know, that there is a distinction between iron melted in an air furnace and iron melted in a cupola. I can show you analysis of iron melted in the one furnace and in the other in which you can not tell one from the other, they are almost absolutely similar, and yet the air furnace iron will yield practically 50 percent excess strength over the cupola iron. There must be something in the molecular arrangement of the atoms of the iron which ordinary analysis for sulphur, phosphorus, carbon, etc., does not disclose. I might use a civil engineering illustration. Good concrete is composed of so many parts of cement, so many parts of sharp sand and so many parts of clean broken stone or gravel. But you only get the best results when you get the very best intermingling of all those elements. And a man might use good sand, good gravel and good cement and yet make pretty poor concrete; he might put all of the cement in one stratum,

all of the sand in another and all of the gravel or stone in a third. If you should analyze a sample of that concrete taken through from top to bottom you would probably find the proportions right and still you would not have good concrete. As these elements seem to form in all sorts of combinations with each other, it would seem as though the ordinary methods of analysis are not sufficient to tell the whole story. I do not know how to explain the fact, but these two methods of melting, although using the same ingredients in the same proportion, give very diverse results in strength, though the analyses are so nearly alike that you could not tell which was air furnace melted and which was cupola melted. By ordinary analysis there is a difference that is not revealed. That would seem to be somewhat of a contradiction of what Mr. Henderson thinks in regard to ingredients and their source, whether smelted with charcoal or with coke in the first instance. It seems to be almost universally admitted that charcoal iron is stronger than coke. Why, I do not know how to explain.

THE AUTHOR: You have probably left out one thing, the statement made in regard to temperature.

I want to tell a little experience. I have been in the car wheel business a good many years. I was at a certain shop where they had a great many difficulties. They made wheels one time out of what was considered the very best charcoal iron that could be had, Salisbury, etc., a mixture which some of the railroad officials have been hoping for the past five years would safeguard the strength, and most of these wheels were very weak and many of them would break at one or two blows of the standard test drop weight. Later under improved methods in shop practice, exactly the same kind and size of castings in that same shop were made without either of those charcoal irons, and in some cases without any charcoal iron, wheels that would stand 100 and 200 percent more than the specifications, showing that the treatment of the metal as it is being melted and the treatment of the metal after it is melted and the treatment of the castings while being poured and after they are poured, are of greater importance than raw materials with which you start.

STEEL CASTINGS

A DISCUSSION

Mr. A. Stucki:* The steel casting is a splendid material and has a great future before it. Unlike cast iron it is strong both in tension and compression, is much stronger than malleable iron and does not need to undergo a chemical transformation after it has been poured. It can be welded, brazed or fused, and can be made tough, hard, or medium, just as the specific service for which it is intended requires. This is generally accomplished by simply varying the percentage of carbon. The metal, however, can readily be mixed with other elements, such as nickel, tungsten, vanadium, titanium, etc., to make it still more adaptable to specific requirements.

Unfortunately it is not often possible to get enough of such special castings in one order, to make a heat, and in this respect the small furnace has advantages over the larger one and the Tropenas converter over the furnaces.

The shrinkage of a steel casting during solidification is $\frac{1}{4}$ in. per foot, against $\frac{1}{8}$ in. for cast iron, $\frac{3}{16}$ in. for brass, $\frac{3}{16}$ in. for malleable iron; hence, patterns made for any of the other metals cannot be used for steel, even if the design would otherwise permit. I have found shops, however, where $\frac{3}{16}$ in. was used for both steel and malleable iron, which undoubtedly leaves the steel castings rather small in size.

Such a high shrinkage, just twice as great as that of cast iron, is detrimental in many ways. Shrinkage cracks sometimes appear. Invariably they are the result of an uneven or rather unfortunate distribution of the metal, which, in many cases, might easily have been avoided in the design. At times, however, it is almost impossible to design a casting to fit into a certain given place, so as to comply with other existing conditions (method of machining or fastening, etc) and yet avoid

* Consulting Engineer, Pittsburgh.

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the danger of such shrinkage cracks. Often these cracks do not exist but the tendency is there, in other words, there are internal strains. These strains, however, can be taken care of by reheating the castings, for which purpose a comparatively low temperature is sufficient.

Castings which are open at one end, for example U sections, the open ends are apt to spread, as the intervening sand will hold them apart; dry sand naturally forming a greater resistance than green sand. This trouble is remedied either by allowing for such spread in the pattern, by closing in the free ends under a press, or by connecting them with extra metal, which will be removed as soon as the casting is cooled. This latter method is often used to hold the pedestal legs of a locomotive frame in place.

But even in a box shape the outward pressure of the sand is often detrimental and if the box is long the shrinkage is great, as is evidenced in a car bolster. Whenever there is a wall at the extreme ends, or whenever varying cross sections prevent a sleeve like slipping, the metal in cooling is subjected to tremendous strain. To overcome such troubles, the cores are sometimes mixed with saw dust or other inflammable materials, to render them honeycombed after being burned out or the cores are made collapsible in other ways.

In driving wheel centers and all similar castings consisting of rims and spokes, the latter cool more quickly than the rim and if not prevented from doing so by covering with sand, etc., will pull inward from the rim, frequently producing cracks in the spokes or arms.

Another result of such large shrinkage is the piping of castings, which cool and reduce in volume, while the source of additional metal is cut off. Large gates and high heads usually obviate this trouble.

When large masses of metal occur which cannot be reached directly by gates, but which are fed by thinner sections of the casting proper, the shrinkage in these masses form cooling cavities in their centers. Such cavities cannot be avoided unless the metal is more evenly distributed. Often such cavities are not harmful.

Steel has to be poured at a much higher heat than cast iron; hence it contains more air and in order to allow it to escape before the casting sets the metal must not be allowed to cool too rapidly. Thin sections are, therefore, detrimental in this respect and ingredients have to be added to offset this, else a honeycombed product will result. A high head or other outside pressure will help to get rid of the air.

From this it is plain that the temperature of the steel, while being poured must be nearly right, hence hand ladles cannot be employed without running the risk of having too cold a metal, and even with the bull ladle care must be taken that the charge is not excessive in proportion to the size of castings, so that it can be poured before the metal gets too cool.

Mr. G. W. Smith:* In foundry methods it is very hard to determine right from wrong. The only way I have to determine the proper method is by the results I get. Some foundrymen buy cheap scrap and cheap material and expect the furnace man to give them a good grade of steel and yet wonder why the castings are not solid and free from hot cracks. This method is wrong especially with acid furnaces. If cheap scrap is the furnace charge cheap castings will be the foundry output, many of which are only fit for scrap to go back to the furnace to make more cheap scrap. To a certain extent what you charge in the furnace is what you will take out.

Some foundrymen buy cheap sand and will change to any kind of sand that is offered at a less cost, and expect their foundry foreman to give them a good grade of castings and wonder why the percentage of bad castings is so high. This method is wrong; if good steel castings are wanted get the foundryman the right kind of sand and clay and stick to it and do not change material when your work is coming good, no matter who wants to sell or what the price is.

In a steel foundry there are eight or ten different departments. The work must pass through each of these depart-

* Vice-President, Union Steel Casting Co.

ments, so it is necessary that one department work into the next for a certain distance, often causing friction between the foremen, thus making it necessary to have one man with some knowledge of all departments over the different foremen. In my opinion no one method can be adopted for all shops, but each shop must adopt its own method to conform with the design of the shop, which can only be obtained by experience in the shop. But all shops can be kept clean and material kept in their proper places, so that when a workman wants something he can get it quickly. A disorderly shop is expensive practice. We have found that the best results are obtained by living close to specifications which have been obtained by experience in the shop.

Great care should be given to the pattern department, as much depends on it for the avoidance of errors in the shop which are liable to prove costly. A forgotten core or error in measurement may mean the loss of a casting. It is good practice to put all patterns and core boxes together after being used in the foundry; this should be the duty of one man who should keep a full record of all patterns and core boxes as the molders cannot be depended upon to do that work.

MR. JOHN ALLISON:* Features of design that are of common application, which should be known by engineers and those interested in the use of steel castings, are frequently overlooked. I shall confine myself to noting a few of these common features.

One of the first problems that confronts the designer is the strength and fitness of material to be used for a given purpose. Steel castings are made that meet requirements ranging from the very hard castings made to withstand abrasion, to the very soft, or low carbon steel castings which are well adapted to withstand shocks and vibration.

Many are familiar with the application of steel castings to a given class of work but are not informed as to the very wide range of requirements, for which suitable steel castings may be obtained. For purposes requiring a hard steel to with-

* Engineer, Pittsburgh Steel Foundry Co.

stand abrasion or wear such as rolls, dies, gears, wearing parts of machines, frogs and hard steel inserts for railroad track work, steel castings are made from 35 to 100 percent carbon. In this class, castings are made by the crucible, converter and basic, or acid, open hearth process. The desired degree of hardness being obtained within a range of about 10 points or less, carbon. For purposes requiring a mild tough steel to withstand shocks or vibration, such as machine parts, connections, parts in structural work, steel boxes, ladles and car castings; most of the castings are made by the open hearth process, many small castings, however, being made by the converter or crucible process. A very wide range of sizes are made by the open hearth process, especially by the basic open hearth. The basic steel possesses qualities of toughness that better withstand the tendency to checking when the casting is cooling. These castings are made from 15 to 30 percent carbon steel. A great many castings are made of about 15 to 30 percent carbon; 2 to 4 percent phosphorus; 2 to 4 percent sulphur; 2 to 4 percent silicon, and 65 to 75 percent manganese. This mild steel has an ultimate tensile strength of 65 000 to 75 000 ℔. per sq. in., an elastic limit of about 38 000 ℔. per sq. in., and an elongation in 2 in. of about 28 percent in a test piece, ½ in. diameter. It may be bent, forged, or welded.

Due to the possible presence of blow holes in steel castings, the allowable safe fiber stress for mild steel is usually taken to be from 9000 to 16 000 ℔. per sq. in. For important work, physical tests should be made of the material to be used, to ascertain the tensile strength and ductility.

The shrinkage in steel castings varies from about ⅛ in. per ft. to over ¼ in. per ft., depending in large measure on the thickness and shape of the casting, and is liable to seriously affect castings made of such form as to be hindered in contraction when cooling in the sand mold. It is of evident advantage to make castings of such form, that large bodies of the sand mold will not hinder this contraction, especially between parts of castings that are far apart.

To avoid internal stresses being set up, uniformity of

section, or a gradual change of cross section is desirable. Annealing reduces the internal stresses.

To avoid shrinkage cracks, or checking in inside angles, fillets should be made larger than is necessary for cast iron, but should not be large enough to cause the metal to be much slower in cooling in the angle than adjoining parts.

The casting solidifies first in the thin parts and when they are held apart there is a tendency to rupture in that portion of the casting connecting them.

Fillets should be proportioned to the thickness of adjoining members. Although open hearth steel castings are successfully made less than ½ in. thick in forms that favor the flow of molten steel, it is good practice to make the minimum thickness ½ in. and ⅝ in. or more is better.

When the size of cores for holes is specified they should be made larger than is necessary for cast iron, because the molten steel cuts or penetrates the sand core, thus leaving the hole smaller than the original size of the core. It is better to specify the desired diameter of the hole required giving size of bolt or rivet to be used. As a common instance, a $\frac{13}{16}$ in. diameter core in a plate of cast steel 1 in. thick does not make a hole large enough for a ¾ in. bolt or rivet, a ⅞ in. diameter core makes a hole nearer the desired size.

Due to the variations in shrinkage a liberal allowance should be made where possible, for variations in dimensions, and for finish, where machining is necessary.

Mr. J. S. Unger:* While listening to the papers it struck me that in addition to knowing how to make castings, how to overcome some of the troublesome features and how to design castings properly, we should not forget something that is very important in steel casting, and that is treatment. I know that the price at which we buy ordinary steel castings today will not justify a treatment that is at all complicated or that will cost much money. However one is almost compelled to use steel castings in some cases, owing to difficulties in preparing a forging of the design suitable for the purpose.

* Manager, Research Laboratory, Carnegie Steel Co.

Following the history of castings we originally began with cast iron, later we made malleable iron and still later we made what are called semi-steel castings, and then steel castings. At the present time in some classes of work, automobiles for instance, they are making special castings of alloys which contain such metals as nickel, chromium, vanadium, titanium and quite a number of other metals alloyed with the ordinary constituents of steel. Some of these alloys have given very excellent results.

One finds that when using a special alloy of any kind, in order to get the best results and develop the best qualities in the steel it is necessary to treat it, not simply annealing, but treatment more or less complicated, depending on the results required. Ordinarily treatment by heating the casting to the proper temperature then plunging it into oil and chilling it, afterwards reducing the hardness produced by the oil, is sufficient. There are special alloy castings in which ordinary treatment in oil is not sufficient but water must be used to obtain the results, the oil not being sufficient to break up the coarse grain or structure.

Steel castings have been made of various sizes from an ounce or two up to perhaps 150 tons. I know of a steel casting that weighed 140 tons that carried about 5 percent nickel and required three open hearth heats to cast it. It had a six-foot core for almost the entire length.

Another thing that impressed me is what the electric furnace had done in the matter of making it possible to produce intricate shaped and very thin welded steel castings. I saw a steel casting not a great while ago which was a fork for a bicycle, 6 in. long with walls not over 1/8 in. thick at any point, cast from steel made in an electric furnace. We had the specimen sawed longitudinally and it did not show a single cavity. It was absolutely as sound as though it were forged or drawn from a piece of tubing. I do not believe that a casting with walls as thin as that could be made in an ordinary steel furnace. It is possible to raise the temperature of the steel in an electric furnace to such a high point that it will flow in as thin a wall as that, while the reducing action of the

electric furnace prevents many of the gases from being occluded. There is not any bubbling or motion at all while the casting is being poured. While I do not wish to specially recommend electric steel casting, I bring that up to show that very small steel castings can be made in an electric furnace. Most steel casting people say that sound castings with very thin walls cannot be made in a steel furnace, and I agree with them. But there is another means of making the casting.

With these special steel castings it is possible to make them the equivalent of a forging by treatment. The effect of treatment is especially noticeable in manganese steel castings. It is a common and necessary practice among those who manufacture manganese steel to heat the article to approximately 950 deg., plunge it into cold water and leave it until it is absolutely cold. This develops the characteristic toughness and increases the hardness to a higher point than it was prior to this treatment.

I believe flask annealing is practiced to some extent. Flask annealing may be a benefit, but I do not believe it is as beneficial as removing the casting from the flask and reheating to the proper temperature, allowing it to cool slowly. In some experiments I had knowledge of, it was necessary to determine what was the best method of treatment to give a large mass. This was some years ago, and I have forgotten the details, but as I recall, it was something like this. There were prepared from one and the same heat four or five solid cylinders measuring about 4 in. diameter and perhaps 6 ft. long. They were cast one right after the other in sand moulds. The first one was laid aside and tested in its ordinary condition; the second was annealed at a temperature of about 900 deg., cooled in the furnace until it had lost all its color and then removed and allowed to cool in the air. The next was annealed at 900 deg. and reheated to 750 deg. and then allowed to cool in the air. The next was annealed twice at 900 deg. The next was annealed twice at 750 deg. After they had been prepared in this way they were put in a large lathe and a nick cut around the outside and broken and the structure examined. I presume you know that in annealing a steel casting

you rarely reduce the tensile strength. If there is any change at all , unless it is a defective specimen, it is almost invariably a trifle higher than in the original casting. Annealing does make a great difference in the elongation. Approximately the elongation is increased from two to three times what it originally was—speaking now of large castings, not small ones.

The cylinder in its unannealed condition, just as it was taken out of the sand, was broken and the structure over the entire surface was examined and found to be very large grains, octahedron in character, from ⅜ in. to ½ in. through the crystal. One blow of the drop broke this cylinder. The next one, that had been heated to 900 deg. and cooled in the furnace until it lost color, also broke at one blow, the difference in structure being noticed for about 10 in. from the outside, the coarse grains having disappeared, but the extreme center was still coarse, showing that the treatment had not affected it throughout, and there was still a central core that seemed to be just as it was in the original casting. The next cylinder, which had been treated at 900 deg. and then at 750 deg. showed practically the same appearance, the effect of the treatment having been felt for about 12 in. from the outside, but the grain was finer than that produced by annealing at 900 deg. only. The next cylinder, which had been annealed twice at 900 deg., showed that the effect of this treatment had been felt almost to the center. There was a small portion, perhaps 6 in., in the center still coarse grained. The next one, that had been treated twice at 750 deg., was very fine for 4 in. to 6 in. in from the outside, the remainder being coarse. The object of using these two temperatures was this: If one can break up the coarse structure produced in a casting or forging at a low temperature you will get a finer and stronger grain. But the coarse fracture that is produced in the large casting that cools slowly in the sand is not readily broken up at a temperature of 750 deg. If one could anneal often enough at 750 deg. I believe we would have a stronger casting than when annealed at 900 deg.; but the amount of work and cost would be excessive. It is not practicable, so most manufacturers try to do their annealing at 900 deg. in order to break

up the coarse structure and get the desired effect at a minimum cost. We afterwards decided that for ordinary large castings, somewhat representing those cylinders I spoke of, there was not enough good effect produced by a first annealing at 900 deg. and re-heating at 750 deg. to justify the adoption of that treatment, and the treatment since that time has consisted of removing the casting from the sand, heating it up to 900 deg. and holding it there when that temperature is reached to allow the casting time to lag. By that I mean to give the grains time to rearrange themselves and allow for that chemical change in the carbon which occurs to a greater or less extent. After the casting has reached 900 deg. one should maintain that temperature for approximately an hour and a half or two hours to be sure that the change has taken place. Then you may begin to reduce the temperature in the furnace. I do not believe there is any real benefit to be derived in allowing a casting to soak a long time in the furnace. When it has reached the proper temperature and is of the same temperature throughout no further good can be accomplished by allowing it to cool down very slowly. After it shows no visible color in the furnace, I would recommend removing the casting from the furnace and allow it to cool in the air. The additional cooling in the furnace is of no benefit to the casting and it only holds the furnace back from further use.

Mr. T. D. Lynch:* I do not know whether I can add anything that will be of special interest to this meeting, but will say that our experience has been outside of the foundry rather than inside of it. We use steel castings in machinery of all kinds and our problem is to get a product that will be satisfactory for our customers. We have had more or less trouble with steel castings from blow-holes, shrinkage cracks, and physical qualities.

It may be of interest to elaborate a little on the subject of testing, with special reference as to how to locate test samples. It is our object in designating the location of test samples to get a test that will represent the real material in

* Engineer of Material Tests, Westinghouse Elec. & Mfg. Co.

the casting as it is to be used in service. What we need to know in any structure of machine is the strength of the structure at its weakest point. To do this it is necessary to take tests that represent the casting in its finished state. If the casting is annealed all test pieces should be annealed with the casting. If the casting is not annealed the test pieces should not be annealed (and any casting is dangerous that has not been annealed). I know of a case where a casting weighing 50 000 lb. had not been annealed, through some error, and this casting exploded when being placed in position on a mill for machining, the casting breaking from its own internal stresses and actually opened up through the middle about 3/8 of an inch while the crack at the rim on either side was still intact, showing the enormous strain that had been set up by the shrinkage effect.

The coupon test is a very usual one to make and the lower it is placed on the casting the better the coupon will be, provided the feeding is good and the coupon so located is less liable to have blow-holes and sand-holes; whereas the nearer the cope the coupon is placed the more subject it will be to flaws and segregation. The design of the casting in general should be such as will permit of its being fed readily from one or more risers. Ordinarily castings are gated from the bottom so that the pouring operation is done through the gate filling up the casting until the metal comes up into the riser, after which the metal is poured into the riser keeping it agitated and heated longer than any other part of the casting so that the casting proper will be fed from the riser during the cooling operation. This riser should be large enough to remain in a liquid state until after the casting itself has solidified.

It has been our practice in a number of cases, in the manufacture of massive castings at least, in order to avoid shrinkage cavities, to make the riser equal in size to that of the casting itself; that is to say, an equal amount of material should be poured into the riser as is poured into the casting. By this method we have been able to obtain castings absolutely clear of all cinders, gas pockets, blow-holes, shrinkage cavities, etc.

The question of riser and method of feeding is not all that is required to make solid castings, but the metal charge must be of selected stock both as to pig iron and scrap used.

In these massive castings we have found it best to take the test pieces from the body of the casting itself after it has had its final treatment by drilling them from the solid casting at a point about ½ the radial distance. By so doing we have felt that we were actually getting the real test representing the steel as it would be under working conditions.

Mr. C. B. Albree:* I know very little about the process of making steel castings but I have been a user of them for riveting machines. In that line of work we have all sorts of troubles, and in coming here tonight I hoped that we who have to design steel castings would receive from the foundrymen some really valuable pointers on design.

The majority of machinery manufacturers who use steel castings in place of cast iron on account of strength and reduced weight, are much more familiar with cast iron than with steel castings. A drawing of the part required is made and the pattern sent to the foundry, but when the casting is received it is often full of blow holes and out of shape. Surfaces requiring planing do not clean up and blow holes and shrinkage cracks make it impossible to use the casting, necessitating a wait of from one to four weeks for a new one. Meanwhile the customer wants to know why delivery of the machine is not made. That is how the user of steel castings often fares. Why it is, he does not know.

Our principal experience has been with riveting machines as shown in Fig. 1, which consist of U shaped parts having a heavy tension section, a lighter compression section and a comparatively thin web. We decided on a very thin web at first and as a result we got a casting that cracked all around the web close to the flanges. The foundryman told us we must have a big fillet to avoid such cracks. Sometimes we found that the foundries were not annealing the castings and we had them annealed which saved a little trouble. We tried putting in ribs to stiffen the web and that made matters worse because

* President, Chester B. Albree Iron Works.

we got cracks along the ribs. We did away with them and now make the web very heavy without ribs. It took us some time to learn these details and we found that the fewer the stiffening ribs and the heavier we made the web, the better the castings. I think it cost the steel casting people a great deal because we did not know how to design steel castings. If they had told us that we were making a mistake in our designs we would have changed the patterns. I think it is often up to the steel casting companies that they have bad castings, because they receive patterns not properly designed and do not advise their customers.

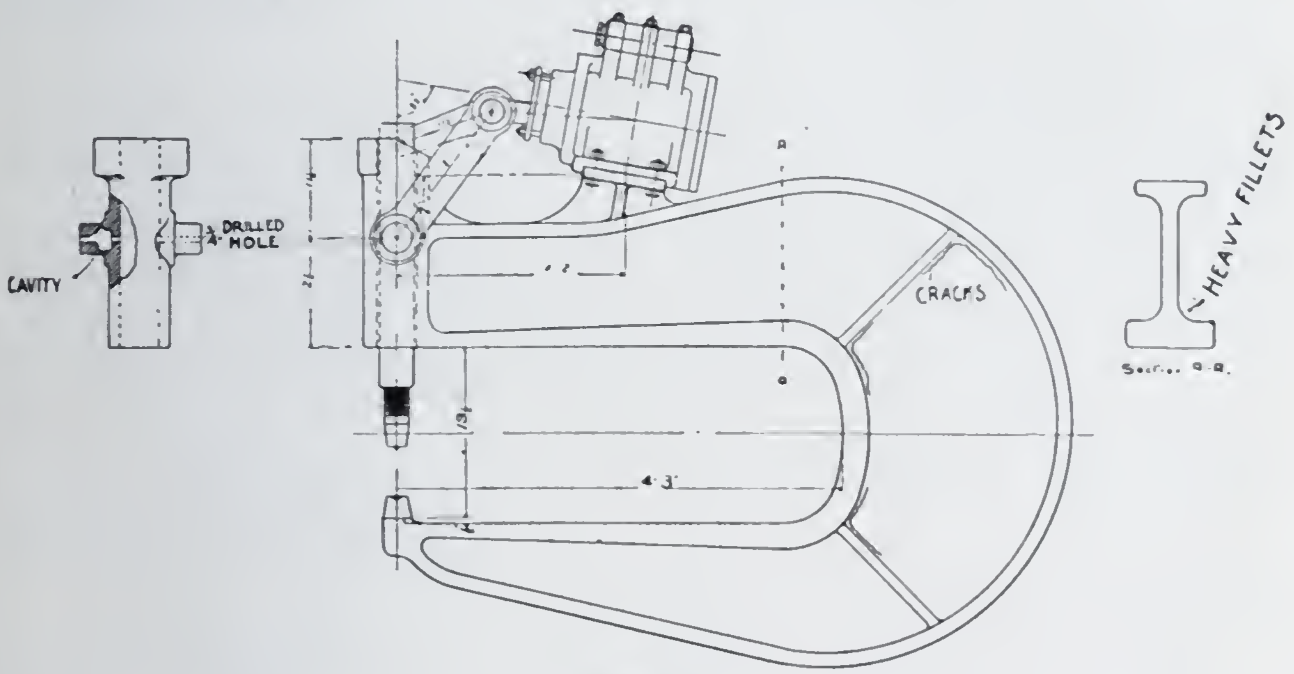


Fig. 1

In the matter of cores, the author said that the cores shrink, making the holes smaller than the core. This is certainly true, the same time we have to machine out those core holes and we have found it very decidedly to our advantage to pay for ½ in. more metal and avoid trying to scrape out scale. In steel castings we cannot rely on as accurately cored holes as in iron castings and it is much better where there is a finished surface to allow ample material everywhere for finishing. Sometimes we had to make a considerable change in measurements of machine parts to make use of the steel castings received, and it is difficult to keep track of such changes when making a duplicate part later.

Another difficulty we met is in getting castings with solid

trunnions. In this particular case we cannot help ourselves as we have to have trunnions. The first thing we do with these castings is to drill a ¾ in. hole through the center of the trunnions and about one out of every four castings has a blow hole, or cavity, in the center. The other portions of the casting may be perfect, yet if the trunnions are defective the casting is absolutely useless as the greatest strain comes on them.

We have taken up this design with almost every steel casting man in Pittsburgh and many outside and practically every one of them has had trouble. The queer thing is that we get three good ones and one bad one. There must be some reason why we get that bad one, and I think the steel foundry superintendent should discover it.

Another point about annealing steel castings. We have received annealed castings from many foundries which came out all right and have received others which from a front view present a badly warped and crooked appearance. The whole thing would be so out of shape, that, while it was a perfectly good casting otherwise, it was so twisted that we could not possibly use it. My conception of this is that they are not careful enough in supporting it in the furnace when they reheat it and there is a bending due to the unsupported weight of part of the casting which sags when it is heated.

We had a machine to build for the U. S. Government that called for a 12 ft. gap. It made a very heavy casting, about 30 000 ℔., and as the pattern was pretty long and difficult to handle the foundrymen, unknown to us, put a piece across the open end of the jaws, 8 in. wide and about 3 in. thick. When we received it, this piece was cast in solid and we had to cut it out, which was a rather expensive operation. After cutting it out, the jaws which were originally 20 in. apart, closed in until the distance was only 17 in. The government threw it out, the steel foundry lost the casting, and we lost the work on it and had to pay a penalty for delayed shipment.

When it comes to small castings our experience has been very bad and we use forgings throughout. Some of our competitors use steel castings, which are considerably cheaper and we thought we would try it. We had patterns made of per-

fectly straight pieces without cores or other troublesome features, and there was no reason why they should not come out right. We tried them on ten different machines and in every case the castings had such blow holes that they were absolutely useless. We have never yet had a yoke break through where the greatest strain is, under loads of from 50 to 150 tons on the outer ends of the jaws. We use a fiber stress of 10 000 to 12 000 lb. in designing sections.

It seems to me that the success of a steel casting depends first on its design and second on the foundry, so the customer and the foundryman ought to get together in order to secure successful results.

Mr. J. S. Unger: I have seen exactly cases such as Mr. Albree describes. However, I am afraid he does not give the steel foundry exactly what I might call a square deal. The steel casting man is up against a pretty hard proposition. Where it is not a question of mechanical strain, I believe the question of soundness can be overcome. But unless the casting has been properly designed it will be difficult for the foundrymen to cast it of the shape required by some of the engineers.

I saw at one time an interesting example in the teaching of a class in one of our technical schools the effects of improper design. Two castings, shown in Fig. 2, were made of cast iron. The casting *A* carried a heavy cross in the center while the outer rim was very light. The casting *B* was exactly the

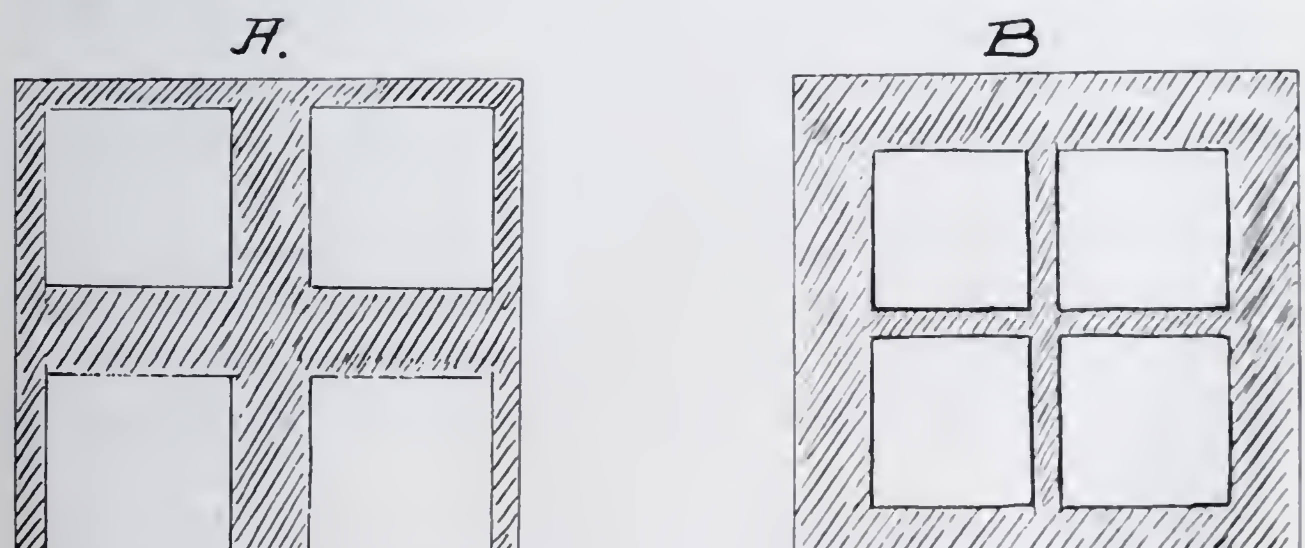


Fig. 2

reverse of *A*. The results of bad design and shrinkage was demonstrated when these castings were removed from the flasks and was a lesson which I feel sure was not soon forgotten by the class.

I believe that when you condemn the steel foundry man for all the errors it is unjust to him. When you consider that the temperature of an open hearth furnace is not over 150 deg. above the melting point of steel, you realize that his means are limited. The steel is being made under oxidizing conditions and absorbs and holds large amounts of gases in solution giving up a portion of these on cooling, producing sponginess. If he could raise the temperature of that steel by means of the electric furnace to almost 1000 deg. above the melting point and make the steel under reducing conditions, he could make sound castings that under ordinary conditions he cannot secure. Say the melting point of steel is 1600 deg., a good open hearth furnace will be about 1750 deg., while an electric furnace will work at 2600 deg.

MR. HENRY GULICK:* The question of the location of the coupon is, I think, important. It is so easy to attach a coupon to every large casting, and it is certainly much preferable to casting the test piece separate, which is often done.

MR. F. J. HALE:† I am on the designing side and am here to find out what the foundryman wants rather than to give suggestions. We have had some large castings made, with very little trouble up to 30 000 ℔., with outside and inside walls, compressible cores and things like that and we succeeded in losing only the first casting. I suppose I should say the foundryman was called into consultation in the designing to make suggestions as to the amount to allow for shrinkage, the thickness of the metal, etc. In those cylinders the metal ran approximately 2 in. all over, although the stresses would call for perhaps 1½ in. in one place and ¾ in. in another. I refer particularly to gas engine cylinders of approximately 40 in. bore.

* President, Gulick, Henderson & Co.

† Engineer with The Westinghouse Machine Co.

Mr. Lee C. Moore:* I want to say a word in defense of the steel casting man. We were using quite a number of steel castings in structures we were building and the other day decided to test one of those structures to destruction, and it was the steel castings that gave us all the trouble. We could destroy everything else but when it came to the steel castings we had to chop them out with cold chisels one piece at a time. I would say further that the people who made those castings had no special instruction whatever.

Mr. J. E. Banks:† There has not been any answer as to that case of the twisting that Mr. Albree spoke of.

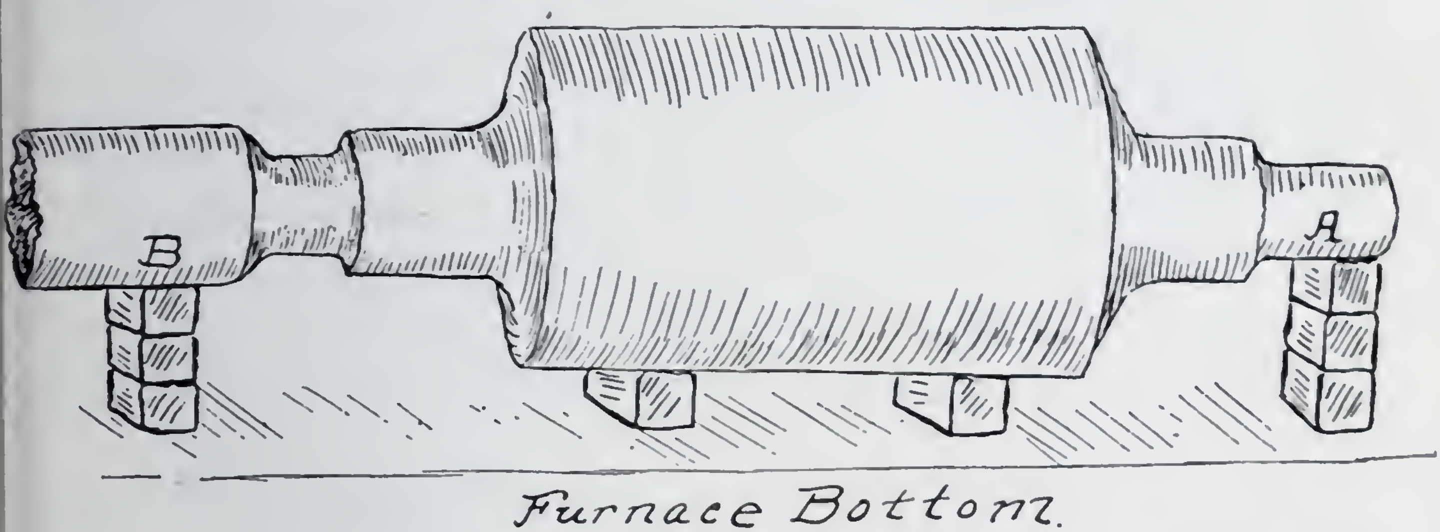


Fig. 3

Mr. J. S. Unger: I do not know what caused that particular twisting but I am inclined to believe that it was not properly supported. In annealing large masses such as a roll, shown in Fig. 3, we placed short pieces of 8 by 8 blooms at *A* and *B* for supports. If the neck at *A* is of any great length we invariably blocked it up to prevent the neck from bending from its own weight. We always had trouble from the extra weight of the sink head at *B* coming down and bending the neck and it was necessary to take these precautions. There are slight distortions in annealing, but not such distortions as would change the character of the casting to the extent described by Mr. Albree. They are not so great but that they would be removed by ordinary fair allowance for machining

* President, Lee C. Moore & Co.

† Engineer of Standards, American Bridge Co.

under ordinary conditions. When you have a case of this kind you must support it in order to prevent the weight of it bending it down and rendering it useless.

Mr. C. B. Albree: Referring again to the cavities, after we had learned to make the web thick enough and to use large fillets and certain other things of that sort, about which I think we should have been advised at the outset by the steel casting men, we still had trouble with the shrinkage cavities in the trunnions. These have caused more loss both to us and to the steel casting men than all the other defects combined. And the peculiar thing that we cannot understand is, why we should get three good ones and one bad one. It was suggested to me by the president of one of the largest steel casting companies that it could be obviated in a very simple way by putting a small core hole through the center of trunnions, so the interior would cool as rapidly as the exterior. We have not tested this scheme but expect to do so soon.

Mr. C. S. Koch: I believe a core will help it out. I believe casting in a piece of cold rolled shafting will be of service. It is a question of unequal volume.

Mr. T. D. Lynch: We have been very successful in eliminating shrinkage by simply making our risers sufficiently large and directly over the casting proper. If the shape of the casting is such that this can be done I should certainly recommend this as the proper method of solving this problem.

Mr. Richard Hirsch:* Is the basic process used to any extent in steel casting?

Mr. J. S. Unger: I believe those people who make large castings, say from 15 000 ℔. up, now make about as many castings from the basic furnace as from the acid furnace. I believe both make good castings. The basic furnace is a little more difficult to handle than the acid. In addition to being an oxidizing it is a purifying process as well. As the steel casting business is difficult at best, one tries to use the easiest method to arrive at results, and therefore they prefer to use the acid method, it being very much easier to operate.

* Mechanical Engineer, H. K. Porter Co.

Mr. T. D. Lynch: We have had good results from both. I agree with Mr. Unger that it is a matter of manipulation, and if properly manipulated I believe that one should get good castings.

Mr. A. Stucki: There are a few points, which I would like to hear discussed a little further. As to annealing, some one said that it reduces the tensile strength while others state just the reverse. As far as my experience goes, annealing improves the tensile strength.

It has been said that for good practice the thickness of the metal should not be made less than ½ in. In ordinary castings I never hesitate to go to ⅜ in. and even that should by no means be regarded as a limit for special cases.

The shrinkage has been said to vary greatly, from ⅛ to ⅜ in., I believe. This is undoubtedly the apparent shrinkage, which is influenced by the resistance of cores and molding sand, by the size and shape of the casting, etc., and if the material could be allowed to freely take its course in cooling, the shrinkage, I feel certain, would be found to be practically the same.

Mr. Smith in his remarks recommends that foundrymen should not change the mixture to economize. He is certainly right about that; but there are many other points where we can economize. In the foundry the small items should be watched just the same as in any other shops. It does not cost more to drive a good rivet than it does to drive a bad one, but it takes more attention and unless a system is adopted whereby a bad rivet can be traced back to the man who did the work, it is almost impossible to obtain close attention. Cleaning castings in the foundry is one of the many items causing considerable expense. If each man is allowed to throw the castings into a common pile after cleaning, one will find many which are not as they should be. With an individual control, such as by requiring the men to place their castings in separate piles, the foundryman will not only get better work, but also greater output, as each man will receive credit for what he does and not for what he should do.

Mr. Albree spoke about losing time on account of steel castings. On the other hand we have often cast details in steel to gain time, when we could not wait for malleable castings, annealing them two days instead of eight, which is greatly in favor of steel castings.

Mr. John Allison: I think Mr. Stucki misunderstood me as to the effect of annealing. I meant only the reduction of internal strains, not of tensile strength. My remarks were intended more in a general way to convey the broadest scope of designs that are made. While many castings can be made successfully less than ½ in. in thickness, and it is common practice to make a great many that way, I think the general run of steel castings could be made to a great deal better advantage if made thicker. This is for the open hearth process especially, and ½ in. or more gives far less trouble to the foundryman, provided the sacrifice is not too great from the point of view of the purchaser of the casting.

In regard to the shrinkage we have seen the variation of various kinds of steel. Basic steel and acid steel are not the same. What I said in relation to variation in shrinkage applies more to the results in the casting, not what would be the result if it were made free. The shape of the casting sometimes causes the casting to shrink less than ⅛ in. between projections on one end having projections, and on the other end it may shrink more than ¼ in.

Mr. L. C. Moore: What in your opinion would be the difference between annealing 15 carbon and 45 carbon steel?

Mr. John Allison: The effect as I have observed it is beneficial in any case. Of course the 45 carbon steels are usually used for altogether different purposes from the 15 carbon steel.

Mr. W. O. Brosius: I would like to ask what difference there would be in the wearing of a rope sheave with a machined groove, the annealed or the one that has not been annealed?

Mr. J. S. Unger: The one that has not been annealed will wear the longer.

Mr J. E. Banks: If annealing relieves all the internal strains, why was it that the jaws closed up three inches in the casting sketched by Mr. Albree, Fig. 1, after the bar was cut out? I understand that the casting was annealed before being cut. Was the bar introduced in the first place to keep the legs of the casting from drawing together or for ease in handling the pattern?

Mr. J. S. Unger: I rather think it was to keep the ends of the U from closing.

Mr. J. E. Banks: If the casting had been annealed properly would the ends have opened?

Mr. J. S. Unger: I think they would have been distorted. The web under tension was probably heavier than the web under compression. Consequently you have a casting that is not properly proportioned. You are getting back to the little problem I sketched which the professor illustrated to his class.

Mr. J. E. Banks: Then annealing does not entirely relieve the internal strains?

Mr. J. S. Unger: No, not in a case of that kind.

POSSIBILITIES OF THE COMMERCIAL AUTOMOBILE

By W. W. Macfarren*

In the presentation of this paper, the writer does not aim to exploit any particular make or type of automobile. Many of the commercial cars now on the market possess many points of excellence. Most of them, also, have their own peculiarities and weaknesses. The good things in use are distributed among a number of cars, so that in order to produce a car having all its elements most approved by present practice, it would be necessary to select from the several cars their meritorious features and combine them in a single car, which, of course, it is impossible to do without a combination of the various makers, owing to the fact that the patents on these several devices are in different hands.

The object of this paper is to show in some measure what has been accomplished in this field, and to emphasize the present magnitude and almost unlimited growth to which this new industry may rapidly attain.

A commercial car may be defined as "A car engaged in the transportation of passengers or merchandise in order to make a direct profit on the operation, or as a factor in profit-making, to which the transportation is auxiliary." In short, the commercial car is a car to make money with, or to save money by, and as it is a direct factor in the production, or non-production, of dividends, the selection of such a car is to be made on a purely business basis.

The question is not only "Am I buying the best machine on the market," but "Am I buying the best machine which it is possible to produce at this time, and am I buying that type of machine which is best suited for the work I have to do?" My advice to the average buyer is to have an engineer pass on the car.

* Mechanical Engineer, Stevenson Building, Pittsburgh.

The automobile is not a new institution. The first steam carriage made in Europe was that of Denis Papin in 1698. Papin's carriage, although only a model, contained a reciprocating steam engine. Twenty carriages were built or under construction, and six or more companies were formed to operate steam coach lines, in London, in 1833.

These early attempts exhibit many meritorious devices, including water tube boilers, air-cooled condensers and shaft and gear drives to the axles. A four-wheel drive was constructed in 1824, in which the rear axle was the crank shaft of the engine, and the front axle was driven by bevel gears and a shaft having a universal joint. In 1829 James equipped a coach with a water tube boiler and separate high pressure engines for each driving wheel, which weighed over three tons and is reported to have carried 15 passengers over rough gravel roads at 12 to 15 miles per hour. During 12 or 14 years Walter Hancock built about ten omnibuses for London service, whose mileage and passengers numbered thousands. His carriage, the "Infant," running between Stratford and London in 1831, was the first motor to carry paying passengers. Adverse legislation prohibiting steam carriages on highways and the competition of horses killed Hancock's efforts. It is remarkable that early builders made only passenger coaches.

MAGNITUDE AND GROWTH OF THE INDUSTRY

The following figures give an idea of the wonderful development of this industry: The value of the product of German automobile factories for 1902 was $2 130 000; 1904 was $9 520 000 and for 1906 was $23 800 000. The imports of automobiles to Great Britain in 1904 amounted to $11 796 000, and in 1906 to $21 274 000.

The following table showing the growth of the industry in this country was compiled by Mr. Charles C. Clifton:

	1898.	1908.
Manufacturers	17	175
Cars produced in year	239	50 000
Persons employed	638	60 000
Value of product	...	$105 700 000
Capital involved	$1 000 000	95 000 000

The "Cycle & Automobile Trade Journal" for March, 1909, listed 153 makers of gasoline, 11 of electric and 3 of steam pleasure cars; also 44 of gasoline and 5 of electric commercial cars; and forecasts for 1909, a production of 75 000 cars in this country, having a selling value of $120 000 000, and made by 253 different manufacturers.

For convenience in this discussion, I have divided the possible useful fields of operation for commercial automobiles as follows: Passenger, Express, Freight and Special service.

PASSENGER SERVICE

Taxicabs and Bus Lines

The use of the taxicab is universal in all cities of Europe, there being 4 000 in London, and is fast becoming so in this country. The taxicab, though a commercial vehicle is in a class by itself, as its requisites embody many of those of the pleasure car.

Hotel and sight-seeing buses are in profitable use in almost all large cities. The latter in some cases at popular resorts have paid their own cost in a 75-day season. These cars have moderate speeds, good furnishings and some sort of rubber tires, though the writer does not consider the latter necessary over good roads.

The automobile bus will undoubtedly be largely used between cities and towns lacking railroad or trolley connections. Such service is readily established where feasible roads obtain, and many lines are in operation in this and other countries. The writer believes that such service will in many cases, compete for moderate distances with all other forms of transportation and will pay large returns in many places where a street railway, on account of fixed charges, would be impracticable; and further that it is possible to compete with existing transportation lines up to distances of 100 miles where fair roads are available and there is a dependable amount of traffic.

In large cities routes could be established so that parties of men could travel at arranged hours between their homes

and offices speedily and comfortably without transfer. The demand for such service would make it pay.

Competition With Street Railways

The writer has long had in mind automobile bus lines as direct competitors with street railways. When the very heavy investment required before opening a city traction line to traffic and the high maintenance charges on tracks, trolley wires, power houses, etc., are considered, such competition by means of properly constructed automobiles seems very feasible. The flexibility of automobile service is superior to that of any service using tracks. In the larger cities a string of ten to fifty cars is frequently seen, blocked by fire, breakdown, or other trouble. A trolley car moves up to the point of impedence and stops. If the automobile cannot pass the obstruction on the same street, it can seek a parallel route. The total disablement of one or several machines cannot tie up the line, as reserve machines from convenient stations can be at once put into service. Fig. 1 shows the Imperial 4-Wheel Drive Electric Truck for passenger service.

In most cities, street car companies are taxed an annual amount per car operated for special privileges on the streets. This tax could not be levied against the automobile, even by a city controlled by the railway company, as the automobile does not require any special privileges, and there are now sufficient automobiles in use so that custom has become a law on this point.

Automobiles for this service should be so designed that they could run in the street car tracks, thus making their competitors provide a track for them. In the opinion of the writer, there is no vehicle on the market today which could be expected to give successful results in such service. However, if such vehicles should be demanded they can be produced, at comparatively short notice. Most of the constituent parts of such vehicles have been separately tried out and demonstrated in existing commercial cars, and it would require only the engineering skill necessary to combine these several elements and the control of the necessary patents to

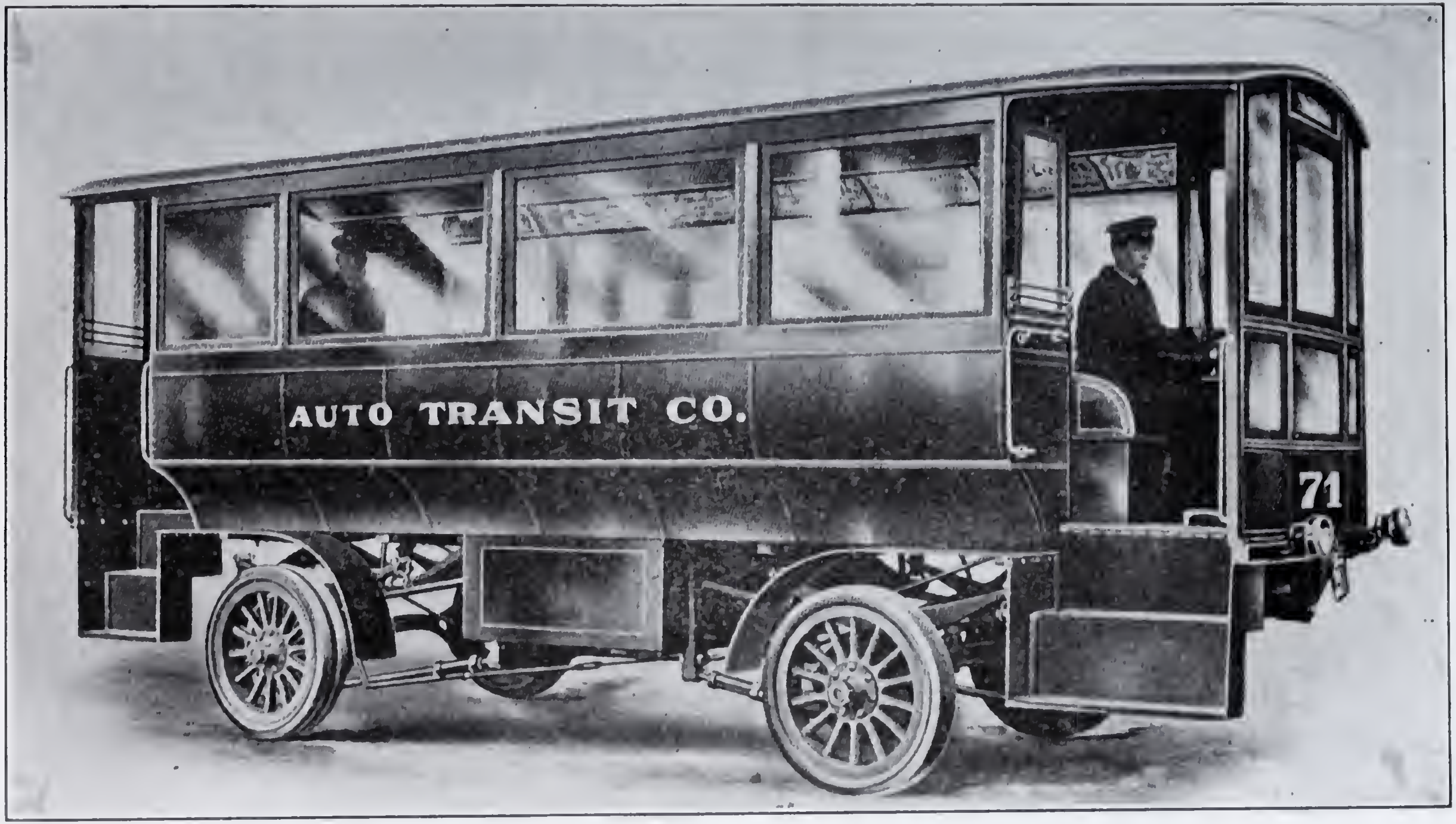


Fig. 1. Imperial Four-Wheel Drive Electric Passenger Car

produce a vehicle fit to enter into competition on the above lines. The time may come when such competition will force street railways into bankruptcy or public opinion will demand the complete removal of the street car tracks and poles which now disfigure our streets.

EXPRESS SERVICE

The commercial automobile is extensively used in deliveries for merchants in nearly every large city except Pittsburgh. In Pittsburgh, while many merchants have partly or wholly equipped their delivery systems with automobiles, the great majority of them, owing to unusually heavy grades and trying pavements, are still using horse vehicles and with good reason as there is hardly an automobile produced which is a commercial proposition for this city. The commercial car, even as now built, can in some instances compete favorably in this service with horses and I fully believe that its development in the near future will make horse-drawn vehicles "back numbers" in the great majority of cases.

W. R. Kuhn & Co., caterers of this city, have used light electric delivery wagons for some time, each taking the place of two horses and one wagon. Mr. Kuhn says, "I believe that when seven to ten or more motor cars are required and they are charged at owner's barn with a careful man to look after them, they can be operated at half the cost of same number of horses and wagons, for an electric wagon can run all day, where a horse must be relieved. We use two horses to each single wagon; generally when we attempt to run one horse all day it soon goes down. My experience with motor wagons for the past three years has been quite satisfactory." These cars carry an average load of 700 pounds each. They make about six trips daily, 20 calls per trip, covering a radius of four miles; and, it should be added, over the best paved streets in Pittsburgh.

The Joseph Horne Company, of this city, used for some time small steam wagons, but have discarded them for gasoline wagons. Six motor cars replace nine horse-drawn

wagons. This firm is steadily adding to their auto equipment, and consider them superior for long hauls, though the cost of the service is greater than with horses.

The Bindley Hardware Company have had a five-ton electric truck, costing about $5 000, in service for several years, operating over the entire city, from their centrally located warehouse in Amberson avenue. The capacity is 10 000 ℔., weight about 9 200 ℔., average daily mileage 25 miles, and the total mileage to date is upwards of 25 000 miles. The batteries are good for about one year's service, and cost about $600 each. The rubber tires used are good for about a year's service, and cost about $500 per set. General repairs will reach about $100 or more, per year. They have their own garage and charging plant. It will be seen that the items of interest, batteries, tires, and general repairs, amount to $1 500 per year, or $5 per working day, or for their service, 20c per mile, without considering general depreciation, cost of current, cost of lubricants, and operators' wages, which will probably bring the total pretty close to $10 per day. At this figure, there is no saving over horse delivery. This company also operates two two-ton gasoline trucks.

In other cities more favorable results have been obtained. Tiffany & Co., New York, operate 21 electric cars, the C. Smit Brewing Company, Philadelphia, 10 electric trucks, and the Adams Express Company, large users of automobiles, discarded 32 horses and 22 wagons in Indianapolis, replacing them with 16 one-ton trucks and 3 two-ton electric trucks. In Chicago, Montgomery, Ward & Co. operate 6 five-ton electric trucks at a daily expense of $8 to $10 each, and Sears, Roebuck & Co. have two heavy electric trucks which are carefully kept up and are never idle except for recharging or repairs. In spite of steady service the cost of transportation is greater than by horses.

A large field awaits the manufacturer of a successful commercial automobile for use by public service express companies. The service in cities would be practically the same as the merchants deliveries, and the same type of vehicle would be successful in both. In such service, the number of

machines, fifty to several hundred, used by one concern, would be sufficient to justify a skillfully planned garage equipped with facilities for repair work, a staff of expert inspectors and repair men, and the concentration of effort to produce dividends would enable the cars to make an enormously better showing than in the hands of any merchandising concern. In addition, the flow of merchandise delivery is usually in one direction only, whereas, the express companies could, in many cases, load both ways.

Such a company, by reason of having the city districted and running wagons to all districts on a regular schedule, in many cases to the busier portions within a few minutes of each other, could contract with the department stores and others having numerous small deliveries to make, and give them quicker deliveries than their own equipment, and at less cost.

The use of auto trucks for interurban express service is developing rapidly both between cities and their suburbs, and cities and towns 100 miles or more apart. Such express lines co-operate very readily with city lines in exchange of express matter, schedules, etc.

In localities furnishing a steady and sufficient volume of business and having fair roads the writer believes it possible to compete with steam railways in long distance express service as the auto truck line is relieved of the necessity for expensive terminals, extensive local delivery systems, rentals to railways for cars and service, the excessive number of handlings of each piece of express matter and the greater part of fixed or operating expenses except for the automobiles themselves.

FREIGHT SERVICE

For general freight service where no railroads exist, the automobile will undoubtedly find a large field as it is entirely possible to construct a commercial car which will run successfully wherever horses can pull an equal load. In thickly populated districts producing a large freight business, competition with railways will probably never be possible except

by water. In the more sparsely settled districts, however, where freight is scarce, competition by auto trucks is entirely possible as the fixed charges on railroads remain practically the same irrespective of the volume of business and the rate per ton mile is much higher with a small traffic; but their larger field in this service will be found in the establishment of freight lines as extensions to and feeders for railroads. Such lines have already been established in a number of instances in different countries. A further advantage is with the automobile in this service in that it can take the shorter route between points.

In this connection it is well to call attention to the possibilities of the commercial automobile as a rate regulator. No transportation company can charge more for a certain service than the price at which the same could be profitably performed by automobiles, if enterprise exists to supply competition. A case in point recently occurred in this city. One of the incline companies had a contract with a local street car company to carry the former's passengers to the center of the city on transfer. At the expiration of this contract last spring, the street car company refused to renew it. The incline company promptly established a service of automobile buses seating about 20 people. After several months' service this summer, the auto bus line was discontinued as a new contract was signed between the companies *on a more favorable basis to the incline company than the previous contract.*

SPECIAL SERVICE

In addition to the more usual uses for the commercial automobile they are peculiarly adapted for several special services. For fire engines they have the advantages of instant availability, greater speed, greater pumping capacity due to less limitation in weight and much smaller standby charges as compared with the horse drawn apparatus. Parallel advantages are found in their adaptation for police patrol and ambulance service. The White Steam Ambulance evidences the possibilities in the latter service. Auto trucks are now

in service for safe moving with capacity for the largest safes and by means of hoisting machinery operated by the driving engine safes are hoisted in a very economical manner.

COST OF TRANSPORTATION

The largest item of operating cost with automobiles in service at this time is that of maintenance which is due, in the writer's opinion, to the fact that the large majority of commercial motor vehicles in this country are not suited for the service in which they are engaged. This item of excessive maintenance charges has kept many hard headed business men from investing in the present designs of motor cars. While it is possible to make paper estimates which show 90 percent of horse-drawn vehicles to be inefficient compared with the automobile, yet it is very difficult to buy a machine which will make good on these estimates.

The Chicago Public Library operates six rubber-tired gasoline cars, with a total daily mileage of 200 miles, an average load of 2 000 ℔., giving 200-ton miles per day. The running expenses for the year ending in April, 1909, were as follows:

Auto parts	$1304.02
Drivers' wages	4500.00
Gasoline	939.23
Tires	968.97
Oil and grease	450.15
Waste	52.44
Machine work	117.01
Batteries	35.02
Supplies	210.78
Painting	199.00
Washing cars	600.00
	$9376.62

Assuming the cars cost $3 000 each and omiting a depreciation charge, as it is claimed that the cars are thoroughly rebuilt each year, the following estimate of fixed charges is made:

Interest at 6 percent	$1080.00
Insurance, at $5 per $1000 per annum	90.00
Storage, (say 100 sq. ft. per car at 50c per sq. ft. per annum	800.00
	$1470.00

The sum of running expenses and fixed charges is per year $10 846.62, and assuming 300 working days the transportation cost is 18c per ton mile. It is to be noted that the operation of these cars is entirely dependable and also that maintenance is over 27 percent of the total operating cost.

The Pittsburgh Transfer Company gives the following average figures for Pittsburgh conditions when about 20 wagons are in service: A single horse will haul one ton 15 miles per day at a total cost of 20c per ton mile and two horses will haul three tons 10 miles per day at a total cost of 16.7c per ton mile. At these figures the Chicago Public Library service would be performed with double wagons for $33.33 per day and with single wagons for $40.00 per day. The actual cost with automobile service was $36.16 per day. The cost of transportation by horses is probably lower in Chicago than Pittsburgh, but the above figures for Pittsburgh are based on an equipment of 20 vehicles while the Library equipment was only six machines.

These figures do not show any very great economy for the automobile. The reason is apparent from the figures given. A single repair account, tires, exceeds the total cost for fuel. The total repair cost is more than twice the fuel cost.

Sidney, Straker & Squire, English manufacturers of steam commercial cars, say: "The position in which a high-grade motor wagon stands today can be briefly summed up as follows:

Compared with horse traction, it will show a saving from 50 percent upwards.

Compared with railway rates, if the usual charges for collection and delivery at each end are taken into account, it will show a saving of about 40 percent.

If the motor wagon has a load only in one direction, it

will generally show a loss in comparison to railways rates of about 20 percent, although under certain favorable circumstances it has been known to show a profit even in that case."

The following estimate is given by the writer as being within the capability of a well designed and well constructed gasoline truck of three tons paying load capacity:

Fixed Charges per Annum

Cost $2500.00 interest at 6 per cent	$150.00
Depreciation at 20 percent	500.00
Insurance at ½ percent	12.50
Storage, 200 sq. ft., at 50c	100.00
	$762.50

which, divided by 300 working days is $2.54 per day.

Running expenses per day for 10 vehicles making 40 miles each per day:

10 Drivers at $2.50, (10 hours)	$25.00
1 Repairman at $3.00	3.00
1 Helper at $2.00	2.00
1 Washer and watchman	2.00
80 Gals. gasoline at 12c, (5 miles per car per gal.)	9.60
Lubricants at 1c per mile	4.00
Maintenance at 10 percent per annum, $2500 per year	8.33
Superintendence at 10 percent of operator's wages (Could have other duties)	3.20
Incidentals,—heat, light, water, tools, waste, losses, etc.	2.87
	$58.00
Each vehicle per day	$5.80
Fixed charges+20 percent for two spare vehicles	3.05
Total operating cost per car per day	8.85
Total cost per vehicle per mile	.22
Cost per ton mile loaded both ways	.0737
Cost per ton mile loaded one way	.1474

On long hauls, such as interurban express service, the above mileage could be doubled, which would increase the gasoline consumption to $1.92 per day per car, the lubricants to 80c per day per car, and the maintenance say 50 percent, or to $1.25 per day per car, making the total cost of operation

per car per day \$10.65, or $13\frac{1}{3}$c per vehicle mile, or 4.4c per ton mile loaded both ways which may be compared with 16.7c, the cost per ton mile for double wagon, loaded both ways as previously figured.

Fig. 2. Four-Wheel Drive Gasoline Truck

It is to be noted that the cost of gasoline in the above estimate is only $16\frac{1}{2}$ percent of the total running expense, and that a difference of 20 percent in mechanical efficiency between two types of trucks would only make a difference of $3\frac{1}{4}$ per-cent on the entire operation. In estimates made by Mr.

Thornycroft not more than 10 percent of the total running expense is for fuel.

Estimate on an Equipment of Ten Five-ton Trucks

Assuming the mileage of each truck at 40 miles per day, the fixed charges per annum are:

Cost $4000 each, interest at 6 percent	$ 240.00
Depreciation at 20 percent	800.00
Insurance at ½ percent	20.00
Storage 250 sq. ft. at 50c	125.00
	$1185.00

Considering 300 working days this is $3.95 per day. Adding 20 percent for two spare vehicles the fixed charges per day are $4.74.

Running Expenses Per Day

10 Drivers at $2.50 (10 hours)	$25.00
1 Repairman	3.00
1 Helper	2.00
1 Washer	2.00
100 Gals. gasoline at 12c, (4 mi. per car per gal)	12.00
Lubricants at 1c per mile	4.00
Maintenance at 10 percent per annum, ($4000 per year, or $13.33 per day)	13.33
Superintendence at 10 percent of operator's wages	3.20
Incidentals	2.87
	$67.40
Running expenses each per day	$ 6.74
Fixed charges each per day	4.74
Total operating expenses each per day	$11.48
Cost per vehicle mile	28.6c
Cost per ton mile load both ways	5.7c
Cost per ton mile load one way	11.4c

The five-ton trucks as above show a saving over horse traction (at 16.7c per ton mile load both ways) of 11c per ton mile or $22.00 per day for each truck. For the usual condition of a load, one way only, the saving would be 21.9c per ton mile, or $44.00 per day per truck.

Assuming that a double truck can be kept on the road for $3.50 per day and will haul 3 tons 15 miles per day

(figures given by Mr. J. J. Blanck of Blanck's Express), the cost per ton mile for load one way is 15.6c and the saving per ton mile for the auto truck is 4.2c, or $8.40 per day, or $2 500 per year. The auto truck when working light one way could return at a higher proportional speed than the horses and could increase its mileage proportionally.

Estimate on Competition With Street Railways

Based on operation of 50 buses, four-wheel drive, steel tires, capacity forty, maximum speed 10 mi. per hr., average speed 8 mi. per hr., weight of seated passengers not over 6 000 lb.

Annual Fixed Charges per Car.

Cost $5000 each, interest at 6 percent	$ 300.00
Depreciation at 20 percent	1000.00
Insurance at ½ percent	25.00
Storage 250 sq. ft., at 50c	125.00
	$1450.00
Add one-third for spare vehicles	484.00
	$1934.00

Pay Roll Per Day.

1 Operating supt.	$ 7.00
1 Chief repairman	5.00
5 Repairmen at $3.00	15.00
5 Helpers at $2.00	10.00
5 Washers and cleaners at $2.00	10.00
1 Traveling "Trouble Man"	4.00
2 Clerks	5.00
1 Dispatcher at barn	3.00
2 Inspectors on road	7.00
	$66.00

Assume average operation of 12½ hours per day, or 100 miles per day, and 365 operating days.

Operating Expenses Per Bus Per Day.

Operator 12½ hours, at 30c	$ 3.75
Gasoline, 25 gals., at 12c, (4 mi. per gal.)	3.00
Maintenance, (outside labor and materials, at 10 percent per annum)	1.37

Lubricants at 1c per mile	1.00
Incidentals	1.26
Car barn and labor charges as above	1.32
	11.70
Fixed charges per day	5.30
Total cost of operation per day	17.00

Assuming gross receipts at the rate of 1c per passenger mile, which is about the same as the average street car rate, (a much higher rate should be charged) on a basis of full seating capacity, the returns would be $40.00 per day, or a profit of $23.00 per bus per day *These buses would pay all expenses if run 43 percent full on a 5c fare for a five-mile haul.*

The plan might be followed of running the buses during the rush hours in direct competition with the street cars and for special service beyond street car competition, as sight-seeing excursions, park cars, etc., at other times.

EXISTING TYPES OF COMMERCIAL CARS

Gasoline Cars

Gasoline commercial cars far outnumber any other type in America and will probably continue to do so, although the fuel may be changed to alcohol, or a heavier product of petroleum. At the present time, there are about fifty makers of such cars which vary in carrying capacity from 500 lb. to ten tons, and in price from $600 to $8 000.

Only one maker has thus far produced a four-wheel drive gasoline car, see Fig. 2. The four-wheel drive worked admirably, but the constructive details of the car were faulty, and the company is now out of business Another variation from usual practice is the International Truck. This truck has the driving wheels in front with standard size wagon wheels in the rear.

The standard American type has the following distinguishing features: Four small wheels of which the rear are driven and the front are steered, rubber tires and the usual lack of protection for working parts. Various gear and

friction transmissions are used and both four and two cycle engines may be obtained either air or water cooled.

In the January, 1909, number of the Automobile Trade Journal, Hugh Dolnar, mechanical editor, says: "*The two-cycle motor is the final heat motor in my opinion,* and can be made to show any power and speed within the resistance of materials by charge volume, and compression increase. With full pure air charge and liquid fuel injection the two-cycle motor can show about 2¼ times the power of a good four-cycle motor, of same bore and stroke; the two-cycle requires less than half the four-cycle cooling effect, for same bore and stroke. All small water-cooled two-cycle motors are very wasteful of power because of over-cooling."

Fig. 3. Walker Electric Truck

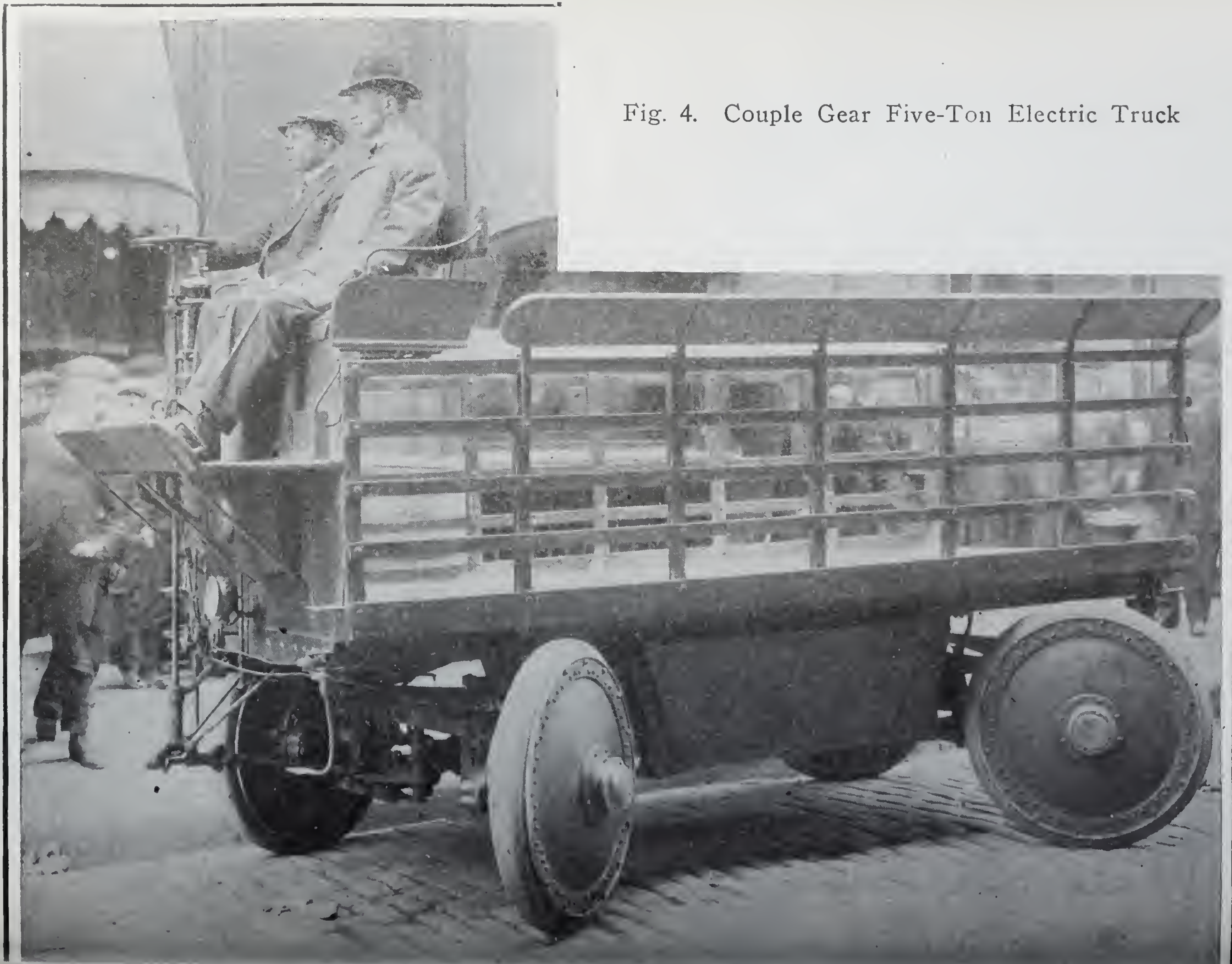


Fig. 4. Couple Gear Five-Ton Electric Truck

The following is quoted from a circular of the Duryea Buggyaut Co.: "The two-cycle motor has practically monopolized the propulsion of small launches because of its extreme simplicity. That it will likewise monopolize the auto is certain. It has been assumed to be less flexible and efficient than the four-cycle, but this is because launches do not require flexibility and it is certain that large steel plants would not use them for large powers if not efficient.

Air cooling has proven itself on cylinders up to five-inch bore for years past and, contrary to the opinions of many, it is particularly adapted to the two-cycle, because these engines do not hold the hot gases longer than necessary to get the power out of them when they are thrown out through large ports and the cool new charge at once enters. Some four-cycle engines use the piston exhaust port, to keep the heat out of the exhaust valve and cylinder heads. And there are no valves to burn and give trouble if not frequently ground."

Electric Cars

Electric commercial cars are made in two types; with storage battery only, and with a trolley taking current from a street car trolley wire and an auxiliary storage battery to allow of short runs away from the wire. Many thousands of storage battery cars are in use and under suitable conditions they give good service. Only a few trolley electrics have been built, and while the idea is somewhat attractive, it will be seen that for city service in the business section where the most business would exist for such a machine, much time would be spent in turning off and on the street car track, and in taking care of the trolley. This car requires a trolley tender.

The distinguishing characteristics of American electric commercial cars are the almost universal use of small diameter wheels, with only two wheels driving, rubber tires, sometimes pneumatic, the large dead weight of the vehicle in proportion to the carrying capacity, and the comparatively short mileage obtainable on a charge.

A variation from the usual type is the Walker electric truck, illustrated in Fig. 3. This car employs pressed steel

wheels, 36 in. diameter front and 42 in. rear, and presents to the writer's mind a more practical design in wheels than any other commercial vehicle of its size built in this country of which he has knowledge; and with the omission of the rubber tires together with the addition of a foot in diameter to the wheels would be very close to finality in electric commercial car design, although such construction would probably not be practicable for an electric truck with present storage batteries.

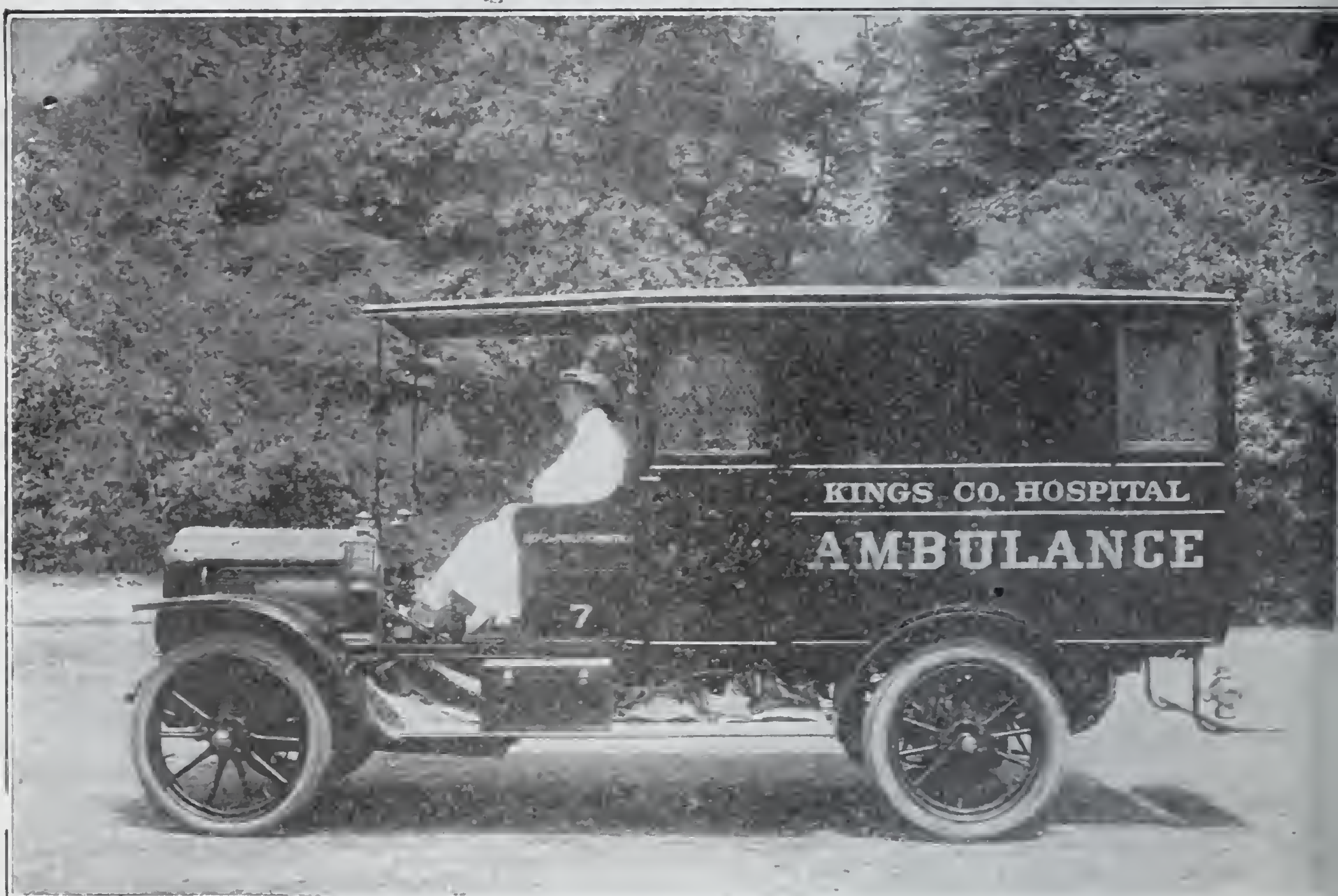


Fig. 5. White Steam Ambulance

Another variation is the Couple Gear Truck, illustrated in Fig. 4. This truck, though still using small wheels, omits rubber tires and substitutes wood, which is a first rate material for traction and cheaply maintained. The chief peculiarity of this truck is shown in the separate motor built into each wheel, so that all four wheels are driven. Also all four wheels are steerable, the action being identical in each, and each

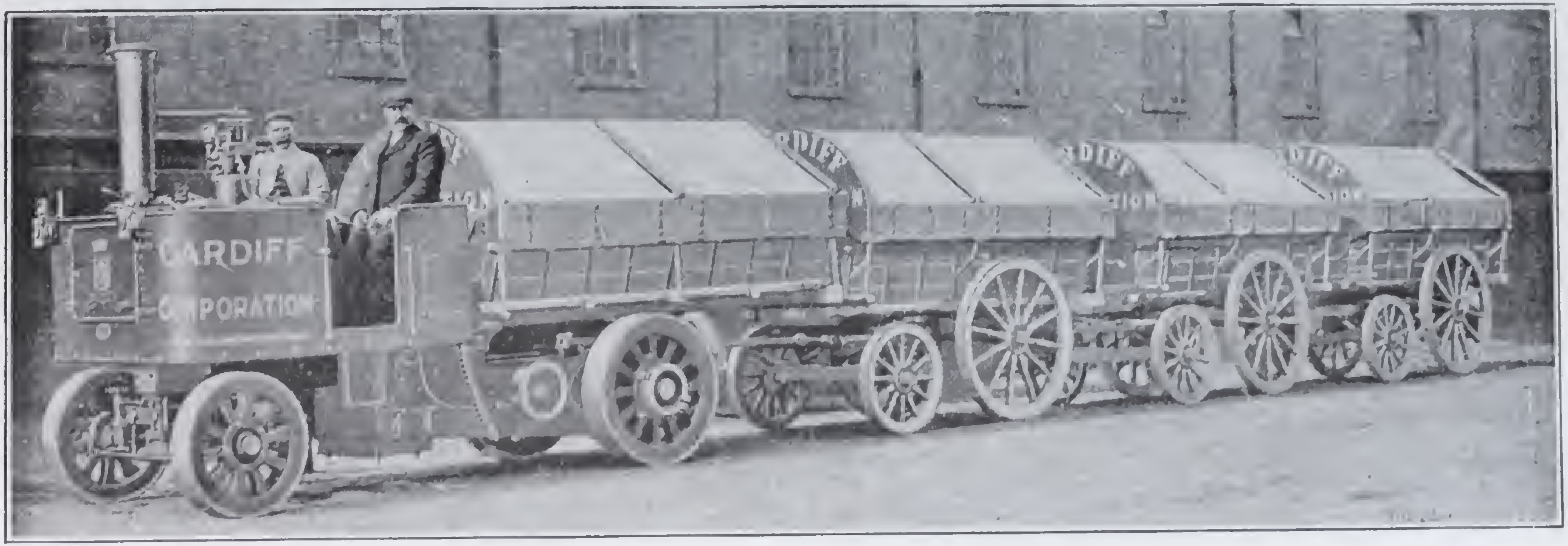


Fig. 6. Steam Wagon and Trailers. Mann's Steam Cart and Wagon Co., Leeds, England

rear wheel runs exactly in the path traversed by the corresponding front wheel. This is true for any angle of steering and when the front wheel clears an obstruction by an inch, the rear wheel will do so as well. The steering action of this truck is beautiful, though not original in this design having been used before, and a large truck can be turned in a very small space, thus adapting itself to crowded city streets.

As an exemplification of correct mechanical principles, this truck is not approached by any other truck at present built in this or any other country, to the writer's knowledge; but in common with others of its class, this car is limited in performance by that weakest of all automobile elements, the storage battery.

Steam Cars

There are practically no steam commercial cars built in this country, although the White Company, build hospital ambulances on the lines shown in Fig. 5, which by reason of their high speed and smooth running, seem to be the ideal power vehicle for this purpose, having advantages over both electric and gasoline cars. Steam cars, however, are extensively manufactured in England, which was the birthplace of this type of vehicle as well as that of many of the component parts of all of our present automobiles.

Illustrations of modern English steam cars are shown in Figs. 6, 7 and 8. I regret to say that many of these vehicles show a higher type of commercial development, and more general adaptability to commercial uses, than almost any cars built in this country. The use of wooden wheels with steel tires, all steel wheels, steel wagon beds, and of spur gear axle drives, places some of these vehicles in a class unapproached as yet by American manufacturers.

Gaso-Electric

Commercial vehicles using both gasoline and electricity for their propulsion have been built for several years, but have never come into extensive use.

A gasoline engine and direct-connected generator are located underneath the seat, and a motor is supplied to drive

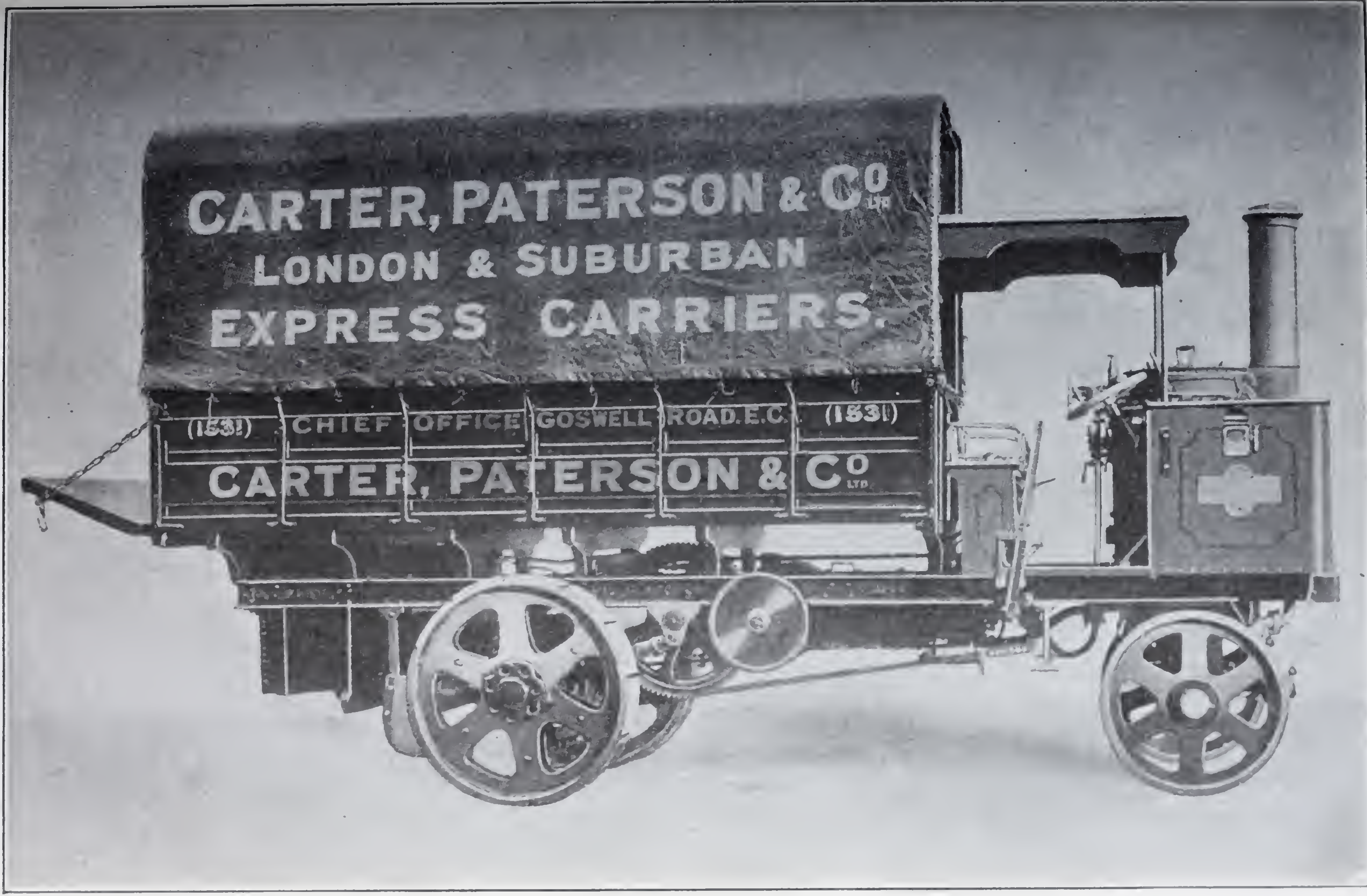
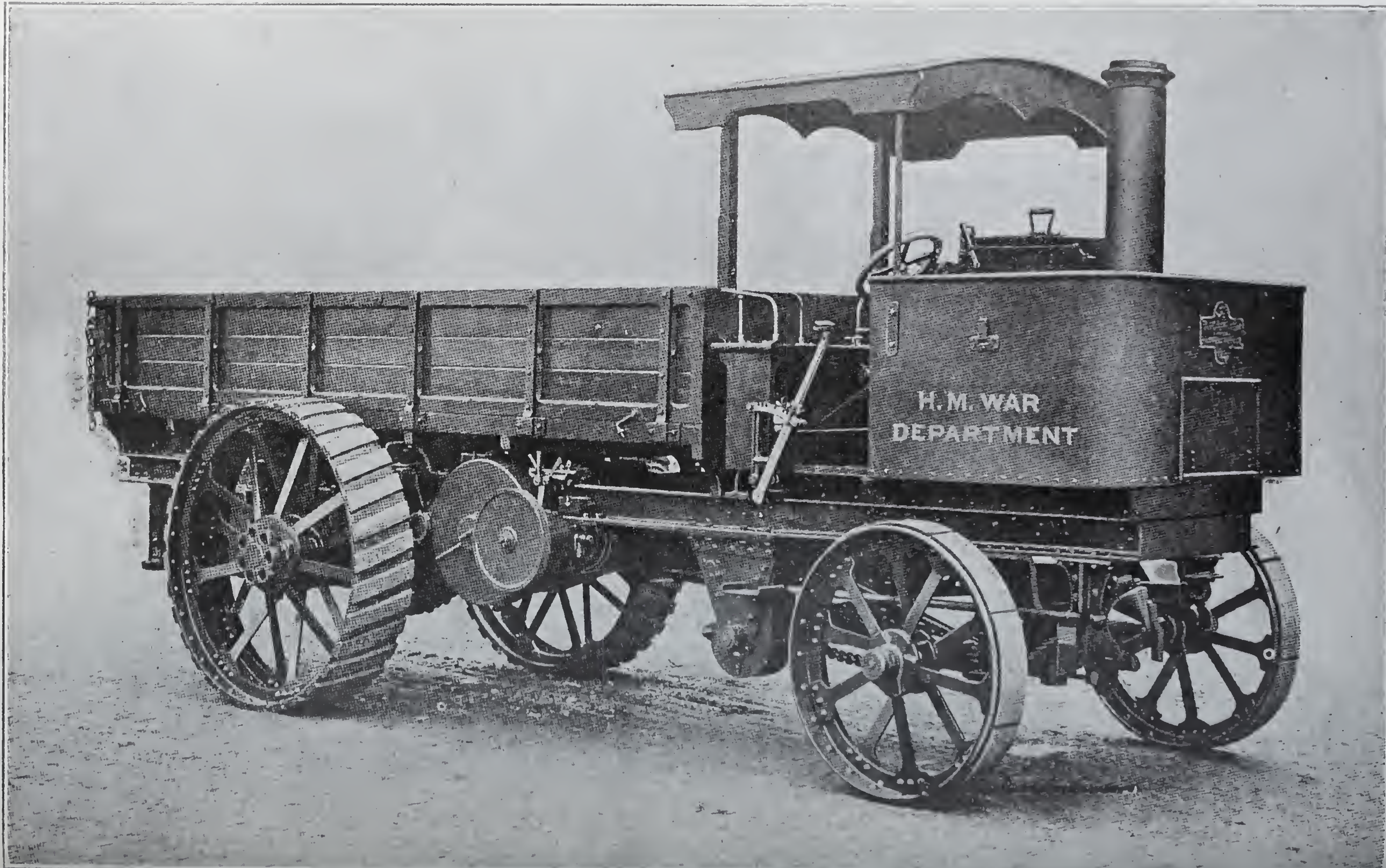


Fig. 7. Five-Ton Steam Express Wagon. Sidney, Straker and Squire, London, England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DEPARTMENT

each rear wheel. A storage battery is carried to assist on overloads which absorbs power on light loads or down grades, so that the engine load conditions are more uniform in this type of vehicle than is usual.

Gaso-Hydraulic

A mechanically beautiful hydraulic drive for pleasure cars is described in a catalogue of the Universal Rotary Machine Co., London. The gasoline engine drives a four-cylinder pump, which supplies oil to two motors, each connected to a rear wheel. On the high speed drive, all the pump cylinders are in action, but when more power is required as when a grade is encountered, the rise of pressure in the pump cylinders due to increased resistance from the hydraulic motors, successively cuts out one, two, or three of the pump cylinders by means of automatic pressure actuated valves.

A form of hydraulic transmission from a gasoline engine has been developed by Charles M. Manley, consisting of a five-cylinder pump having radial cylinders with plungers driven from the same crank pin. The stroke is variable from zero to a maximum, and oil is pumped to two motors, each with chain drive to a rear wheel. This drive dispenses with clutches, change gears and brakes. Control is by a single lever, which in mid-position locks the wheels as they have not sufficient leverage to drive the motor and pump backwards. The forward motion of the lever brings the throw of the pump up from zero to the maximum, with any desired degree of adjustment, thus controlling the speed. Reversing is accomplished by changing the direction of flow of the fluid.

With an engine having a governor to impose a limit of speed, it would seem that a vehicle of this kind could be placed in the hands of anyone who is fit to drive horses, and the sacrifice of mechanical efficiency involved in the transmission would be much more than counterbalanced by the simplicity and flexibility of control.

In the December, 1908, issue of the Automobile Trade Journal, Hugh Dolnar says: "I believe the friction drive is the only thing suitable for a motor car, and am well aware

that my opinion does not accord with practice, nor with the weight of engineering opinion. I do not wish to be understood as recommending any form of friction drive now in cars offered for sale. I believe that front wheel driving is better than rear wheel driving, and *that all four wheels driving and steering will be the finally accepted motor car practice.*"

Gaso-Pneumatic Cars

The writer has made preliminary designs for a gaso-pneumatic truck, embodying some original features, as shown in Figs. 9, 10, 11, 12 and 13. As compared with present practice the following desirable elements are included in this truck: Large diameter wheels, steel tires, four-wheel drive, power steering, air brakes, elastic variable speed drive, maximum speed limit, self-closing control valve, air cooled two-cycle engine, compressed air starting and two-point spring suspension; and the following undesirable elements are omitted: Rubber tires, change speed gear, radiator and pump, engine valves, bevel gears, drive chains and all wooden parts.

The principle of operation is similar to the gaso-electric machines. A two-cylinder, two-cycle, engine is geared to a four-cylinder air compressor, both are air cooled and mounted on the same sub-base. This unit is placed under the seat of the vehicle above the springs, a door being provided at each end of the compartment and the seat hinged so that the complete power unit may be lifted out and another one substituted.

The running gear consists of an I-shaped combination comprising two cast steel axles and a central tubular reach bar, made of steel pipe. The reach bar is fixed to one axle and engages a sleeve bearing in the other; or the reach bar may freely turn in both axles. Each wheel is mounted on a stub axle, similar to the front wheels of an ordinary car. Fastened to this stub axle, and steering with the wheel, there is a small two-cylinder compressed air motor, with all working parts enclosed and running in oil. This motor has only three moving parts and is provided with a pinion which meshes with a spur gear, bolted to the wheel.

The wheels are of steel, at least 48 in. diameter and pro-

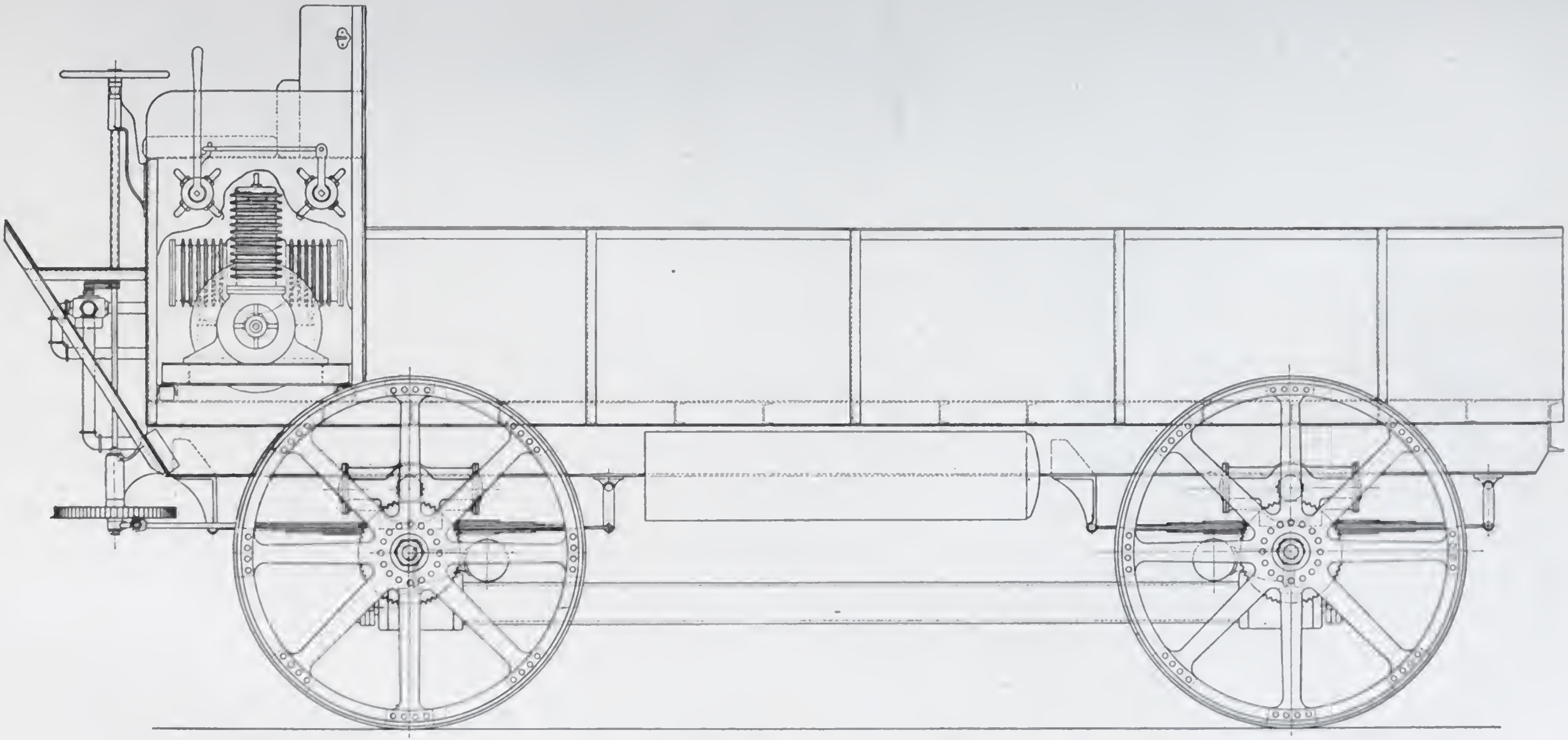


Fig. 9. Preliminary Design for Gaso-Pneumatic Truck, Side Elevation

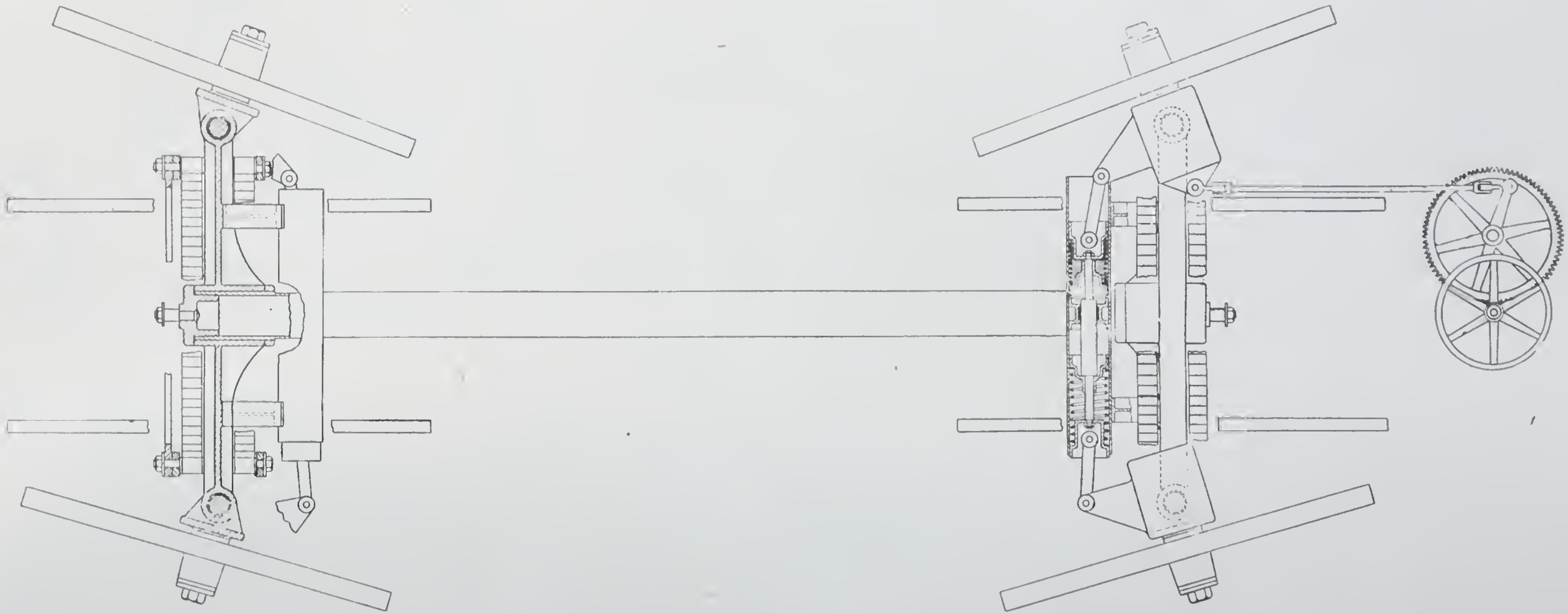


Fig. 10. Preliminary Design for Gaso-Pneumatic Truck, Plan Showing Steering Action

vided with steel tires of a width depending on the load and the roads. For city use it is desirable not to exceed a width of tire or a gauge which will run in the street car tracks, as does an ordinary wagon. The running gear, wheels, and body of this vehicle are all steel, no wood being used in its construction.

An air reservoir comprising two or more light steel tanks is swung under the body. About 20 percent of the reservoir capacity, is in constant communication with the compressor forming the working reservoir, the remaining 80 percent contains air at the maximum pressure to be used for hill climbing and emergencies. There is always sufficient stored air available to run the vehicle out of the line of traffic in case of stoppage of the gas engine.

The aggregate power of the eight motor cylinders is two or three times that of the engine. The compressed air passes through the working reservoir and on to the motor cylinders. the control valve being on the driver's seat. The motor exhaust is led through a closed system of piping back to the compressor, effectually excluding dust from the working cylinder. Oil is supplied to this closed system, automatically lubricating the compressor and motor cylinders, the same oil being used repeatedly. This arrangement gives a much higher thermal efficiency than is usual in compressed air practice, as the air is delivered to the motor within a few seconds after compression, before losing much of the heat of compression. and expanding in the motor cylinder, delivers practically all the work put into it, except friction losses and a slight loss due to radiation. Further the temperature of the motor exhaust is lower than the atmosphere so that the compressor is supplied with cold air. The efficiency of this transmission compares favorably with many forms of gear transmission.

The gasoline engine runs under control of a governor, at a speed much more uniform than is possible with an ordinary form of power transmission to the wheels, and at a speed which cannot be exceeded by a careless operator. A compressed air self-starter is provided avoiding necessity for

cranking the engine and the waste of gasoline when the vehicle is standing.

The flexibility, smoothness and ease of control of this vehicle are unapproached by anything but a steam machine, and the mileage limits are only set by the gasoline carrying capacity and there are no fires. Reversing is accomplished by the four way control valve which reverses the direction of the air through the motors.

Steering is accomplished by compressed air, all four wheels being steerable. Each axle is provided with an air steering cylinder in which air pressure overcomes the resistance of springs which normally keep the wheels in a straight line. This steering gear is elastic, both when running straight and curving, which would be dangerous for a high speed vehicle, but which is of advantage on a slow speed, heavy car. The wheels can be separately steered by the use of separate four-way valves which can be connected by a link so as to be operated simultaneously.

The spring suspension of this vehicle is of novel design. The axles are so located that the weight is practically equal on all wheels, and is transferred to each axle by a pair of transverse half-elliptic main springs, connected at their centers to one member of a hinged joint on the longitudinal center line of the vehicle body so that the latter is free to tilt toward either side. The outer ends of the springs are fastened to the lower ends of links swung from the axle, which are connected by a compensating device, permitting vertical travel of the body, but preventing side swing. These main springs are designed to carry about 80 percent of the weight above them. Owing to the flexible running gear, and the pivoted arrangement of springs any one or two diagonally opposite wheels may rise or fall simultaneously, without disturbing the distribution of the weight, or producing undue strains in the parts.

In order to balance the weight of the body upon the pivots, a separate set of light balancing springs are employed, having a prolonged central leaf with shorter leaves on each side, so arranged that they will act to resist either an upward

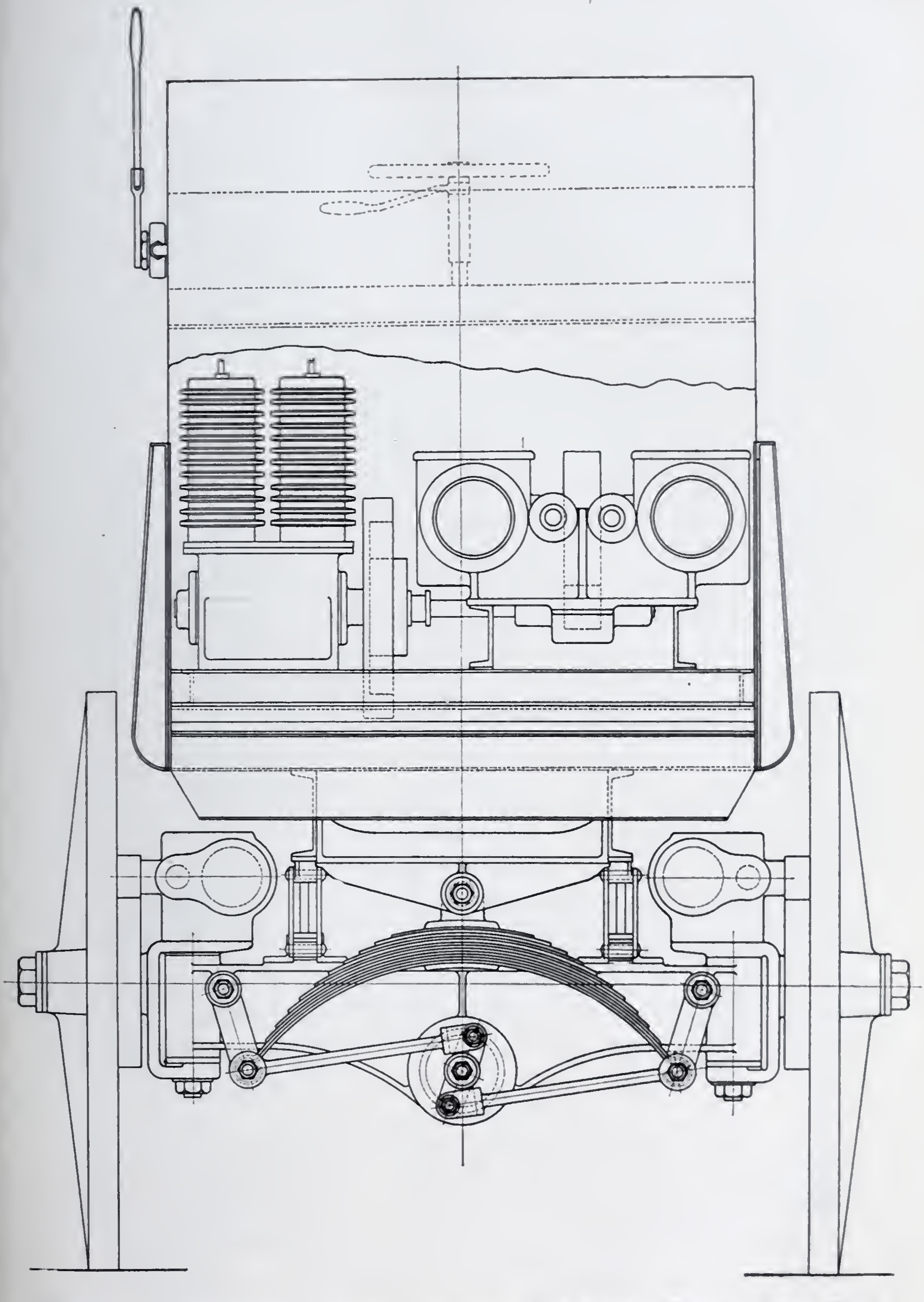


Fig. 11. Preliminary Design for Gaso-Pneumatic Truck, Rear End Elevation

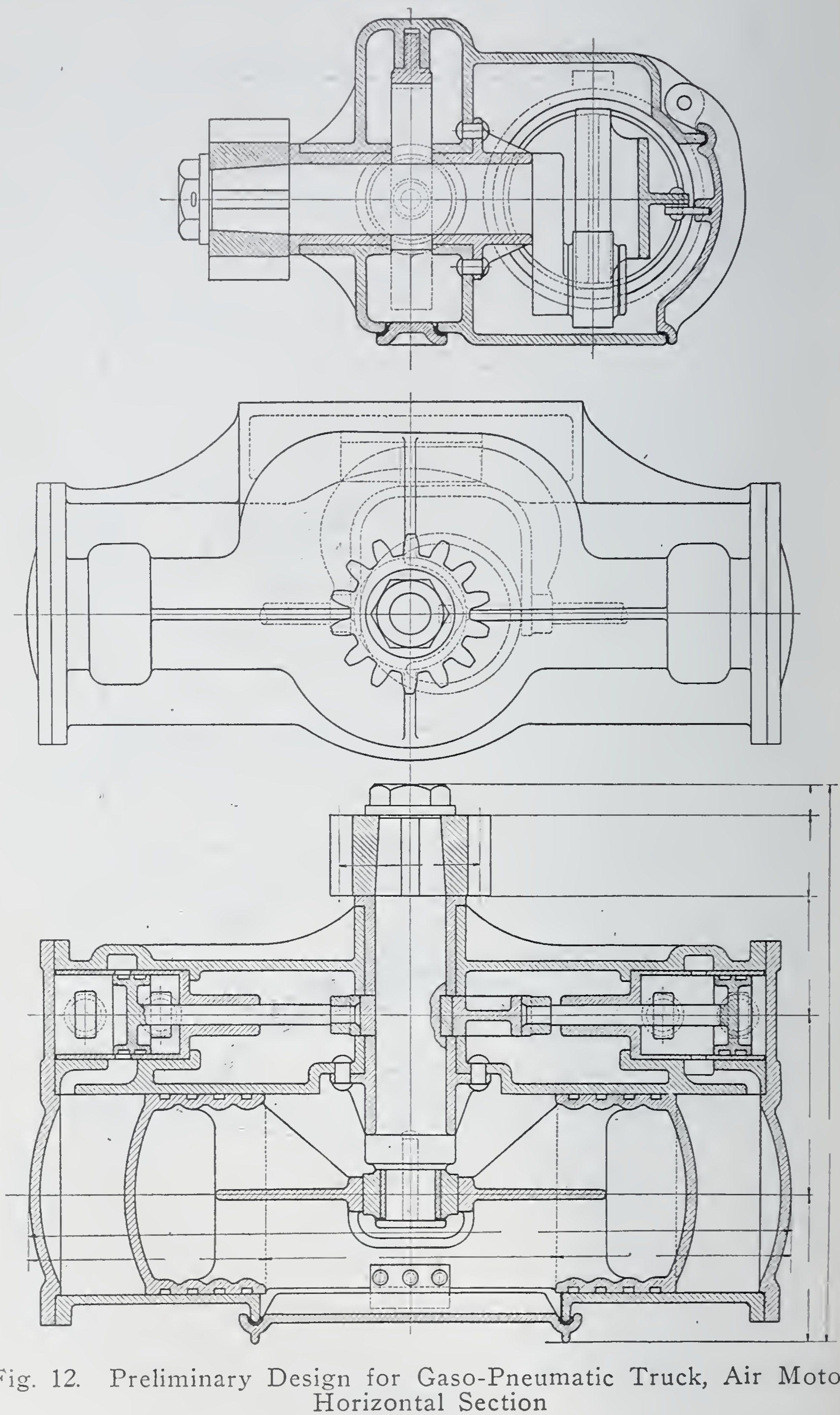


Fig. 12. Preliminary Design for Gaso-Pneumatic Truck, Air Motor, Horizontal Section

or downward pull of the body. With normal loads the balancing springs are straight, and as they take vertical loads in either direction, the tendency of the body to tip out of level will be resisted by all four springs. With this arrangement the transverse springs carry the greater part of the load, and the weight will be substantially evenly distributed, no matter what the position of the wheels on the ground may be.

If the vehicle have a light load, the balancing springs may be flexed upwards in opposition to the main springs which, in this case, would carry the entire weight of the body and load and in addition a certain load from the balancing springs. With heavy loads the balancing springs carry a small proportion of the weight, as they are flexed downwards by the extreme deflection of the main springs. The balancing springs should be practically under no load strain when the vehicle is under its average working load. Under these conditions, with double acting balancing springs, all four of these springs would be in condition to act immediately to preserve equilibrium. The proportional amount of weight carried by the main and balancing springs will depend upon the conditions of service, the speed, condition of road, etc. The division of weight between the two sets of springs would also depend upon the type of vehicle; a low vehicle for heavy loads and low speeds, would have extremely strong main springs and comparatively weak balancing springs; while a high pattern vehicle, as an omnibus for high or moderate speeds, would have comparatively stronger balancing springs, owing to the greater measure of centrifugal force at higher speeds, and the higher center of gravity.

THE COMMERCIAL CAR PROBLEM

The commercial car problem may be stated very simply and fully, as follows: To construct the car which will deliver the most ton miles for a dollar.

Commercial Efficiency vs. Mechanical Efficiency

In a commercial automobile, mechanical, electrical, thermal or similar efficiency, while not to be decried is of little

moment except as it contributes to commercial efficiency, which is everything.

Representing commercial efficiency by E; cost of operation by C; and ton miles of load by $T\ M$, an equation may be written:

$$E = \frac{C}{T M}$$

The items entering into C are: interest on the investment; depreciation; insurance; overhead charges; housing; attendance; fuel and lubricants; operators' salaries and maintenance. Sufficient experience is available so that the number of ton miles for any given road and weather conditions can be closely arrived at, and the first eight items of cost can be predicted with extreme commercial accuracy, but the last item in the present state of construction is a very uncertain factor, and is more than any other single consideration, the most powerful force acting to retard the adoption of commercial automobiles today.

Almost any maker will guarantee the mileage of his vehicle on known roads with a known load. He will also guarantee the fuel and oil consumption not to exceed a certain amount, but as far as is known to the writer, there is no manufacturer of this class of machinery in the United States today, who will sign up a tight contract positively guaranteeing the purchaser of the vehicle against maintenance expenses of more than a reasonable amount, proportional to the service rendered as determined by experience with horse drawn wagons, street cars, or locomotives.

The term mechanical efficiency, as applied to automobiles, is the ratio of the brake horse power developed by the engine to the power applied to the wheels; or the ratio of the heat supplied in the fuel to the foot-pounds as delivered at the wheels. Power is almost invariably one of the cheapest items in manufacturing or transportation industries and even with gasoline at 15 cents per gallon, the fuel economy, which depends mainly upon the mechanical efficiency of transmission, is so small an item compared with reliability, ease and flexibility of control and other desirable operating characteristics,

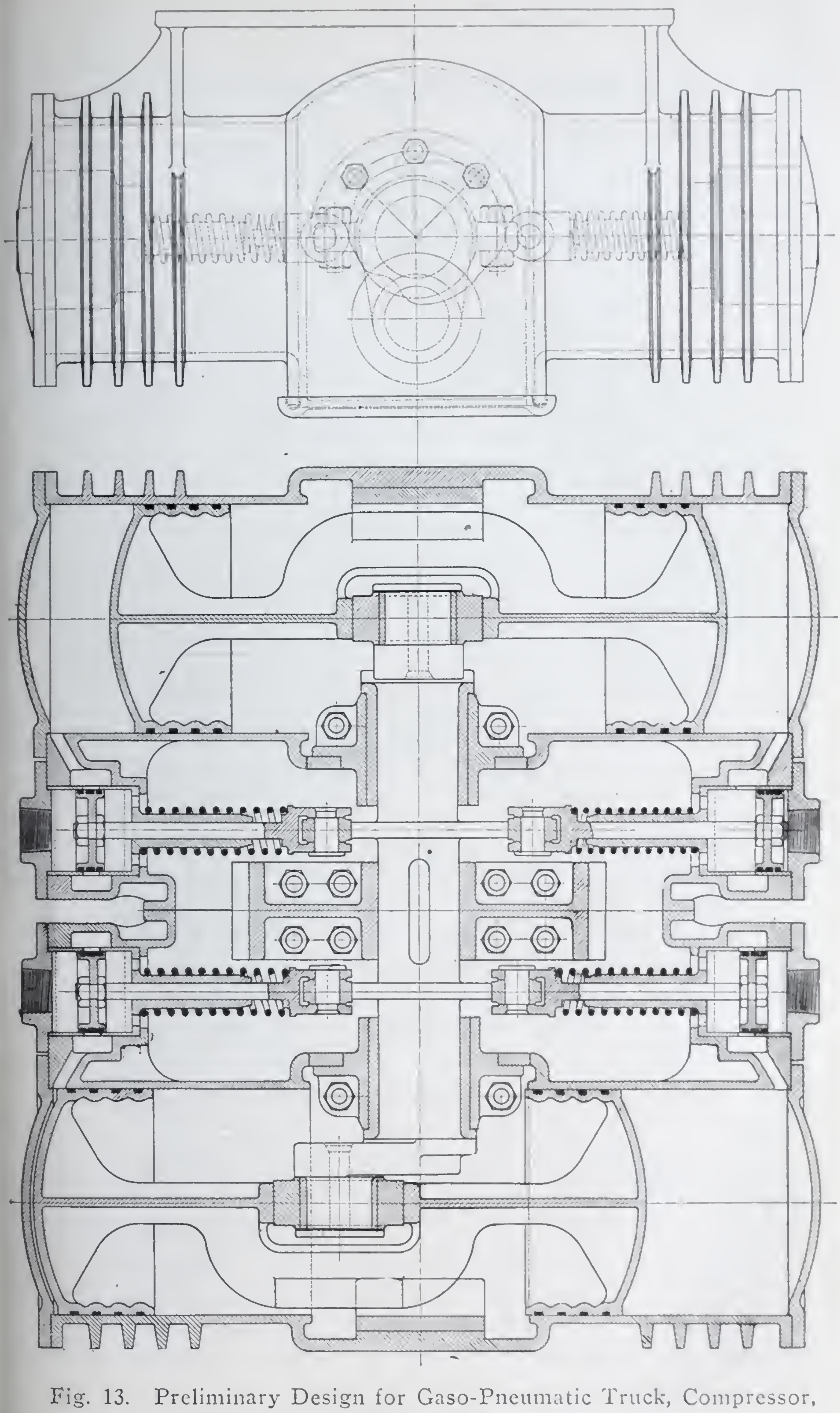


Fig. 13. Preliminary Design for Gaso-Pneumatic Truck, Compressor, Horizontal Section

that it may be practically ignored. This may not always be the case. The construction of commercial cars may reach such perfection that fuel economy will be a distinct point in their favor, but this is not true today, and will not be so for some time to come.

Four-wheel Drive vs. Two-wheel Drive

To the writer's mind it is axiomatic that all four wheels of the commercial car should be driven. This is directly contrary to present practice, with two exceptions, that of the Couple Gear electric truck mentioned, and the Four-Wheel Drive Wagon Company, of Milwaukee, which, until its recent failure, was engaged in the manufacture of gasoline trucks.

Practice in similar services has conclusively demonstrated that while under the best operating conditions it is not always necessary that all the weight should be available for traction, yet it is desirable that it should be so available when needed.

In locomotive practice, it is customary to put as much weight as possible on the driving wheels. In street car practice, the awkward expedient of applying four motors, one to each axle of an eight-wheel car has been used to secure sufficient traction.

In the use of the "Couplé-Gear" trucks, with four-wheel drive and wooden tires, skidding is almost unknown. It is possible, of course, with an icy road on a steep grade to slide the wheels of any self-propelled vehicle, but it may be stated without fear of contradiction, that a four-wheel drive automobile having wood tires or steel tires slightly roughened or corrugated, will pull a load under any condition of road surface, which can be negotiated by a comparative number of horses.

In this connection, the "Couple-Gear Freight-Wheel Co.," in their catalog, say: "Driving from the front wheels has many inherent advantages and permits the use of large rear wheels equipped with *steel tires,* which draw easier and reduce the maintenance cost. To *pull* out of a rut or over an uneven road, is much easier than to *push* through the same place. The driving force is always in the direction in which the

vehicle is guided, while in driving from the rear wheels the driving force is sometimes nearly at right angles to the desired direction of travel. It is of great assistance to be able to swing the drivers for a "new bite" when in a slippery place. When the rear wheels are in a rut or depression, an increased leverage is had by swinging the front or pulling wheels, as is often done with a horse drawn vehicle. The four-wheel drive is absolutely essential for vehicles of large capacity and enables the successful use of inexpensive wood tires."

The following is quoted from the Scientific American, June 24, 1905: "The great traction and control secured by a four-wheel drive is shown by the photo of the machine dropping off the curb slowly and closing a watch case without breaking it. The truck can be backed up against a 12-inch curb and made to climb it from rest. In doing this feat, the ammeter needle jumped only to the 150 point for a brief instant, which corresponds to a 100 percent overload of the motors, an overload which is never exceeded. So effective is the traction that the truck was able to pull stalled horse-drawn trucks out of the snow last winter, even when equipped with *steel tires*."

The writer has seen a rubber tired omnibus, with rear driving wheels only, which had a carrying capacity of twenty people, absolutely refuse to ascend a three percent grade covered with a half-inch of dust, mixed with a few rain drops, when it contained only one passenger; and further, the slight efforts which could be exerted by the writer and the passenger on the rear end of the bus were sufficient to make it ascend the grade.

The application of the four-wheel drive is not easy, but it is far from being impossible, and the advantages to be obtained much more than compensate for the increased cost of construction. There are about seven ways of accomplishing this known to the writer:

The electric drive as used in the Couple Gear truck;

The gaso-hydraulic drive with motor for each wheel;

The gaso-pneumatic drive with motor for each wheel;

In either of the above cases the four-wheel drive could

be obtained, with front wheel steering only, by the use of three motors;

The arrangement used on truck shown in Fig. 1, where the wheels of the four-wheel drive were driven by universal joints;

By the use of a nest of three bevel gears to drive each wheel, the middle gear being mounted on a prolongation of the knuckle steering pin;

By the use of an invention of the writer, comprising a pair of toothed gears acting as a jaw clutch when the wheels are straight and as bevel gears when the wheels are steered, the tooth action being confined to the steering periods;

And when the front axle is steered as a whole, a power shaft can be led down through the steering trunnion; or a sprocket or gear can be universally mounted on the axle and held in operating alignment by guides so that the axle can be thrown at various angles.

On large power vehicles steering by power is advantageous and can be easily arranged.

Mr. Arthur Herschmann, in a paper read before the American Society of Mechanical Engineers, considers that large driving wheels, say four feet in diameter would answer much better than a three-foot wheel, such as are now in use on motor wagons, not only does a four-foot wheel allow of more powerful torque, but it also saves the driving gear by not sinking so deep as a small wheel when passing over a depression in the road surface. He thinks that if a practical arrangement for driving through all four wheels could be introduced, it would prove an excellent feature in a wagon.

Chains vs. Gears

It has been claimed that chains are more efficient power transmitters than bevel gears. This, in the writer's opinion, is far from being the truth; but admitting, for the sake of argument, that it is true, the chains lower materially the commercial efficiency of the vehicle, not only by increasing the cost of maintenance, but by decreasing the reliability.

The following quotation is from the catalog of "Mann's Patent Steam Cart & Wagon Co., Ltd., Leeds, England: "We have from the first adopted the experience gained years ago by traction engine makers, and have used steel toothed gear wheels. Chains and other devices were tried and discarded for heavy road traffic a generation ago, and if confirmation were needed we can point to the fact that no maker of gear driven wagons has discarded gearing for chains, although the reverse has happened. A chain drive is of necessity heavy, and its breakage on a hill is a most serious accident, as all means of control is removed instantly. With toothed gearing, on the other hand, even if a tooth breaks there are other teeth in gear, and control is retained. This ensures safety at the time, and allows the engine to be worked with care until the new wheel is received."

Most Economical Speed

Considered merely from a mechanical standpoint, the economical speed of commercial automobiles will naturally be low, and the writer believes that for ordinary service a speed of ten miles per hour should not be exceeded, except for very light vehicles, and that speeds of four to six miles per hour are ample for the heavier class of vehicles. This belief, however, is based more upon the necessities of the vehicle than the demands of the service. Many cases may arise in which these speeds may be greatly exceeded to the betterment of the commercial efficiency, for it must not be forgotten that one of the chief advantages of the automobile over horse traction is the ability to go further in the same time.

Steel Tires vs. All Others

Commercial vehicles in this country are almost universally equipped with rubber tires. However, the vast majority of all road traffic is carried on steel tires, so that it cannot be contended that the merchandise carried demands rubber tires and the reason for their use is that automobile builders are afraid to send out cars without rubber tires. In the case of the electric vehicle, there is a good reason for this as the storage battery is an extremely delicate apparatus. Steam vehicles with

steel tires are extensively built in England and are operated up to such speeds as are probably desirable for vehicles of their power and weight and no valid reason exists for not placing them on gasoline driven cars. It has been claimed that a vehicle having two driving wheels would not be able to obtain sufficient traction with steel tires. If this is the only objection to the use of steel tires, however, it is of little moment, as there is no question but that four steel tired wheels would drive a vehicle anywhere under ordinary road conditions, for it must be remembered that the traction of steel on a common road is superior to that of steel on a steel rail.

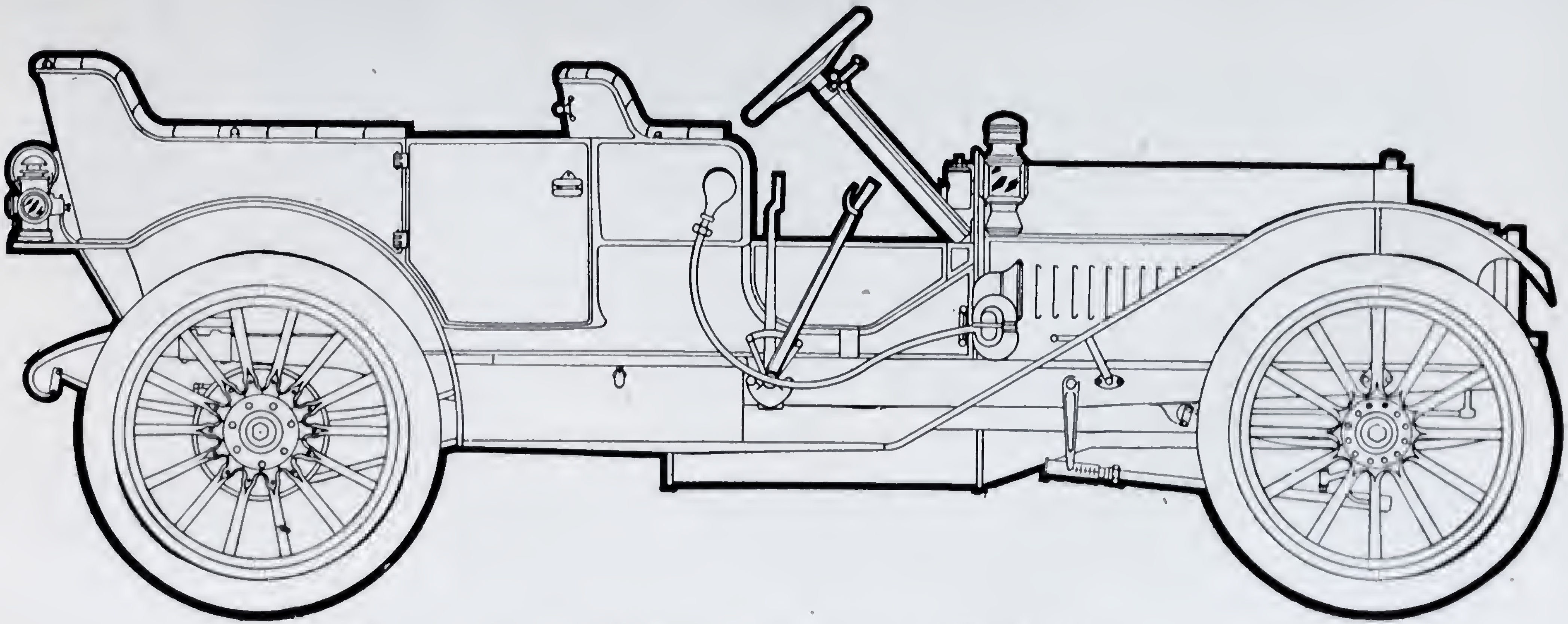
Fig. 14. Duryea Buggyaut

The tire up-keep on all commercial vehicles is one of the most disturbing factors in the computation of commercial efficiency. The writer believes by the use of larger wheels with steel tires and the four-wheel drive, that rubber tires can be eliminated entirely from commercial car service.

As regards wheels, Mr. Herschmann, previously quoted, believes that no form of rubber tires will give satisfaction on a commercial wagon intended to carry a net load of one ton or more, as they not only are expensive but give poor satisfaction under the combined action of great weight and speed. Well constructed springs of ample proportion, he thinks, is the proper way of lessening the shock to which a wagon wheel is subjected.

SPRINGS

Many automobiles are provided with springs to suit a theoretical, rather than an actual, road. Ordinary roads will vary a foot in places from a plane surface and the springs are



Fig, 15. Oldsmobile Touring Car With 42-in. Wheels

supposed to absorb the inequalities of the road as well as to reduce the shock of striking them.

Many cars have a four-point suspension with one spring for each wheel. It is manifestly impossible to pass over large inequalities in the road without twisting the frame or disaligning the drive of the car with this arrangement.

A better construction is the three-point suspension, with two longitudinal springs in the rear and one transverse spring in front. This construction enables the front axle to pass over rough roads more easily but offers no improvement at the rear over the four-point suspension.

The Marmon touring car uses a pair of springs forming a three-point suspension at both the front and rear axles making a double three-point suspension for which very smooth riding is claimed. This is probably as good an arrangement as the market affords today.

Theoretically, a two-point suspension is needed. If an I-beam supporting a flat box is laid across the centers of two axles, the effect of the rise or fall of any wheel would be divided by four when it reached the center of the box. Now if a transverse spring is placed over each axle, and the I-beam raised so that it rests on the center of the springs, the conditions will be the same, except that the necessary elasticity for road travel has been introduced. We have not yet, however, secured stability for the box, as it is unstable equilibrium and can fall to either side.

Assuming the vehicle drawn slowly by horses, and the box filled with say five tons of gravel, and exactly balanced on the I-beam, a man on each side of the vehicle would be able, with but slight exertion to keep the box level by means of levers secured to the sides of the box. The main duty of a set of springs is to support the weight upon them, and if this weight be substantially balanced, as is usual in loading a vehicle, a comparatively slight amount of force is necessary to preserve its balance.

It will thus be seen that if transverse springs are pivoted to the body of the vehicle, so as to allow free vertical motion of the wheels, and a set of balancing springs are provided to

Fig. 16. Frayer-Miller 3-Ton, Air Cooled, Gasoline Truck

maintain the equilibrium of the body, the problem is solved, and any one, or two diagonally opposite wheels may rise or fall without disturbing the level of the vehicle or producing excessive strains therein.

Ease and Flexibility of Control

These characteristics are of the utmost importance in the motor vehicle. The rate of travel should be capable of being controlled from an almost imperceptible movement up to the maximum with one lever, if possible, and by a series of gradual increments rather than a few abrupt steps. In this respect, the control of the steam vehicle is ideal, as an easily operated valve gives any speed from lowest to highest, and the same valve can be used for reversing if desired.

One of the strong points claimed for the electric car is ease and flexibility of control, but it does not approach the steam vehicle in this respect, and while considerably ahead of the average gasoline car as at present manufactured, yet there are several methods by which electric control may be fully equaled by gasoline wagons. These are, first, the use of friction transmissions, by means of which the speed control can be effected without gear changes, and by gradual and imperceptible acceleration; second, by a gaso-hydraulic or gaso-pneumatic combination.

The braking of a car is almost as important as the driving. In addition to the usual hand brakes applied to all vehicles, electric cars can be braked by reversing the motor, but this is a dangerous process. The steam vehicle can be braked by the reversal of the engine without damage to the machinery unless too forcibly applied. The gasoline car having a friction transmission possesses an ideal brake in the transmission, which can be applied instantly to the position of full reverse without danger to the mechanism, and when this is done brings the vehicle to a quick and gradual stop without shock.

The braking of the gaso-pneumatic vehicle designed by the author is not excelled by any other form of brake, as by reversing the air motors a braking effect of any desired intensity may be obtained by the elastic action of the air.

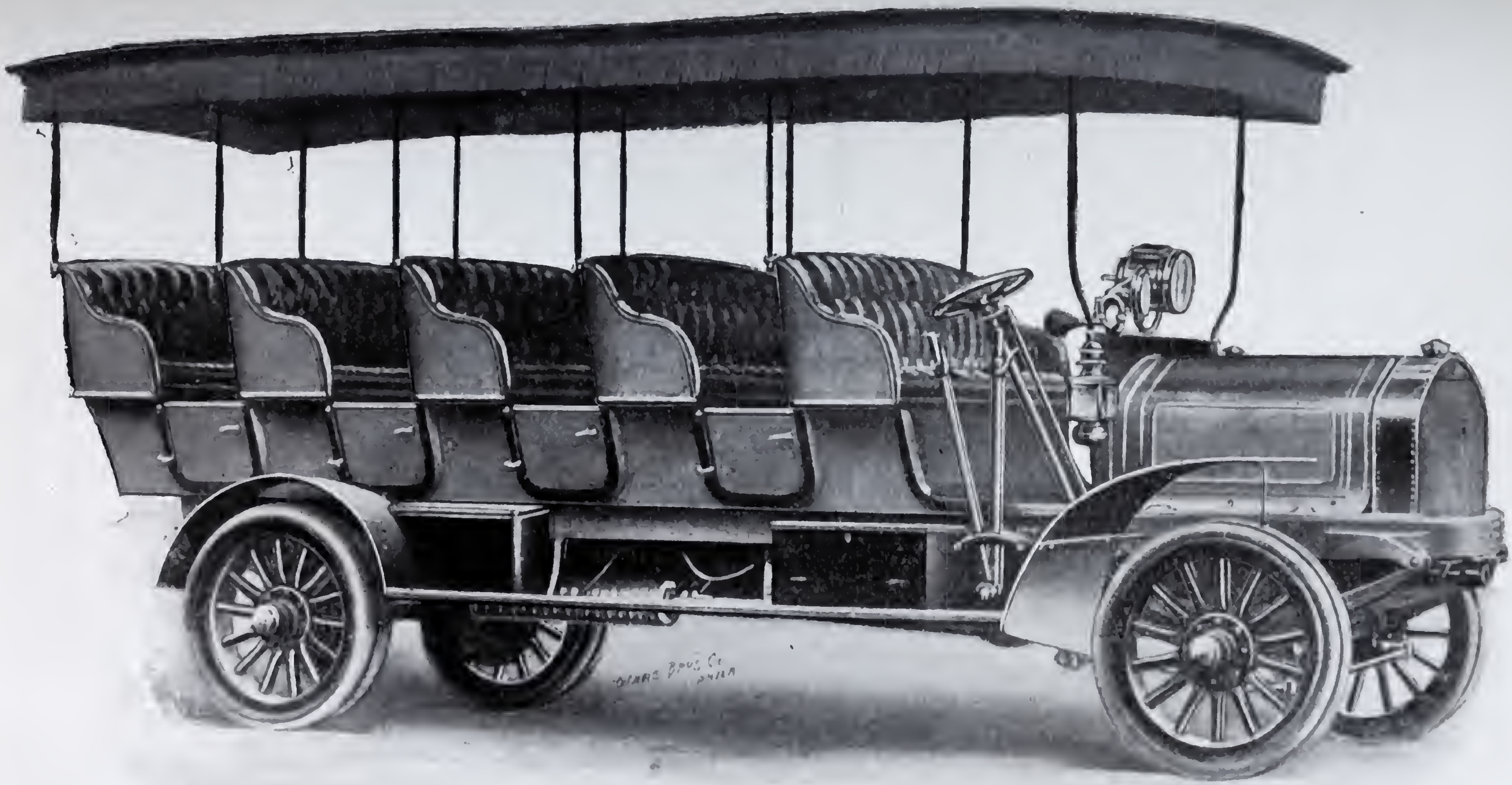


Fig. 17. Mack Bros., Twenty-Passenger Gasoline Bus

Reliability

Reliability is of prime importance in a commercial car. Notwithstanding the many faults of construction embodied in the present cars, their reliability is even now equal to that of horses. The trouble is that this reliability is maintained at too great a cost. The automobile will perform its daily service under weather conditions in which horses absolutely falter. Electric automobiles have been known to run unimpeded in hail, sleet, and snow storms in New York City, when the drivers of horse drawn wagons would not dare to venture from their stables.

Wheels

It is believed that in many cases doubling the size of the wheels and using steel tires would give equal protection to the machinery of auto cars with a corresponding reduction in the power required. It is to be noted in this connection that the use of small wheels necessitates larger and more costly springs than with large wheels in order to secure the same protection to the machinery and load.

The pneumatic tire has been the means of setting a very faulty style in commercial vehicle wheels. Owing to the excessive cost of rubber tires, even on small wheels, most of the commercial vehicles manufactured in this country, are equipped with wheels of ridiculously small diameter for road use.

Mr. Charles E. Duryea says in the Automobile Trade Journal: "I find that where I cannot get satisfaction out of solid tires on small wheels, even though the tires were of large diameter, I do get practically the same speed and comfort up to 15 or 20 miles per hour out of small solid tires on large wheels as with pneumatic tires on small wheels. The pneumatic tire swallows the inequality, while the large wheel bridges it. The large wheel with narrow tires cuts through mud and snow, which take power for the wide air tire on a small wheel to get through." Fig. 14 shows an Oldsmobile Touring Car with 42 in. pneumatic tires.

Wide wheel treads are advantageous as they require less

power on ordinary roads, improve them, and reduce the cost of road maintenance. On hard roads it has been found that they have no effect on traction.

Wheels constructed entirely of steel are used by a number of manufacturers of commercial cars in England and have been adopted by several American manufacturers.

Steel Wagon Beds

The same reasons for making commercial automobile beds of steel obtain as for railway freight cars. Such construction can be made lighter than wood at but little, if any, greater cost and which will outlast three or four wooden bodies.

Fig. 18. Saurer Gasoline Truck With Air Self Start.

STANDARD COMMERCIAL CARS

The road on which a pleasure car is to run is almost always unknown to the manufacturer who has learned by experience to construct cars which will go on any road. This experience, however, does not apply to commercial cars as the buyer usually has in view a route of limited extent which

can be shown to the maker of the car. In the writer's opinion, the commercial automobile should be designed for the exact service which it is to perform, or rather, sufficient types of vehicles should be provided so that a suitable selection can be made. The usual practice is to build several types of cars or several sizes of the same type, of a design supposed to cover all road conditions. In many cases such cars go into operation in places where extreme road conditions do not exist, and while it is difficult to imagine just how a motor car can be too

Fig. 19. Packard Ice Truck

well built, yet it is evident that a standard car suited for the worst conditions is naturally more costly than a car which may be equally well adapted to perform the work in hand, and yet be unable to cope with extreme conditions.

A number of types of gasoline commercial cars are shown in Figs. 16 to 22.

THE IDEAL COMMERCIAL CAR

The ideal commercial car may be defined as one which can travel anywhere a two-horse wagon can travel; one as easily controlled as a team of horses; which can go twice as

fast and four times as far in a day; which will not run over a fixed maximum speed; which will average 40 to 80 mi. per day; and which, all things considered, will do twice the amount of work at less than the cost by horses.

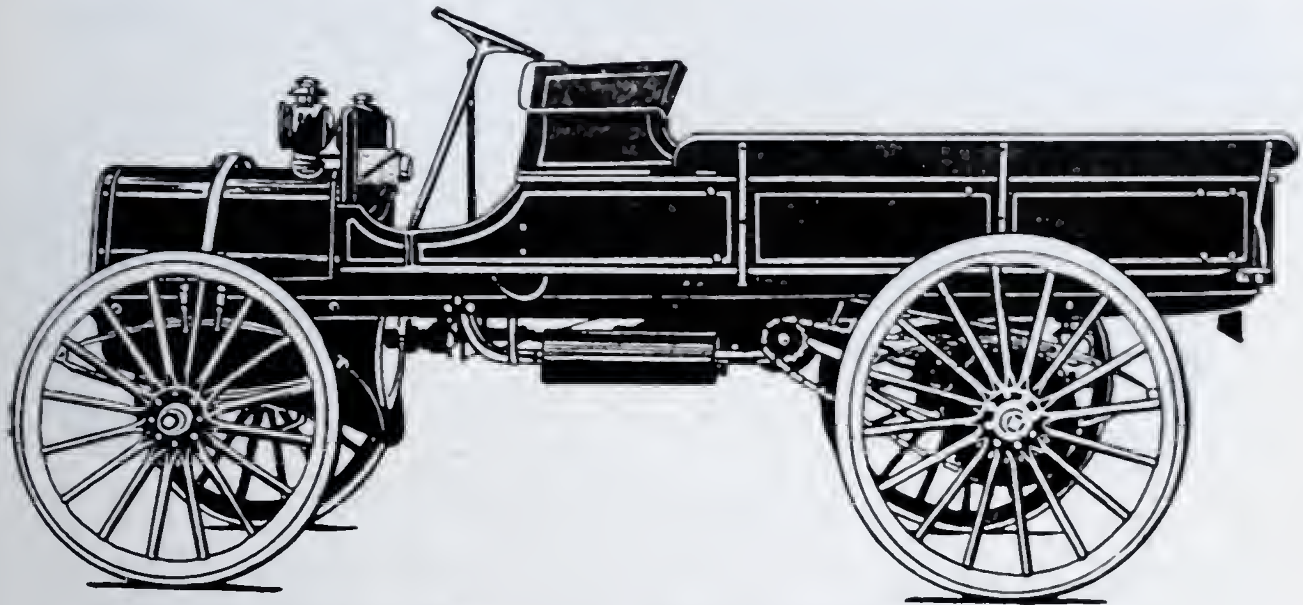


Fig. 20. Chase Two-Cycle, Air Cooled, Delivery Wagon

While such a car is not on the market today, it is not for the reason that it cannot be produced. Had the boom for pleasure vehicles become exhausted several years ago, leaving the manufacturers of such cars in a depressed state, there is no question but that the above ideal commercial car would have been on the road today.

COMMERCIAL AUTOMOBILE INVESTMENTS

The manufacturer of a successful truck has promise of a steady growth of business, even in the face of considerable competition, which is not exceeded by any other line of manufacturing in the world today.

In addition those commencing the manufacture of commercial trucks at this time, have available the years of experience of the pleasure car builders, which has cost in the aggregate, millions of dollars. Dozens of manufacturers in this country are now producing gasoline motors of proven worth, and at this date there are patents which may be purchased which would give the purchaser a practical monopoly of several of the most important types of vehicles for the next fifteen years.

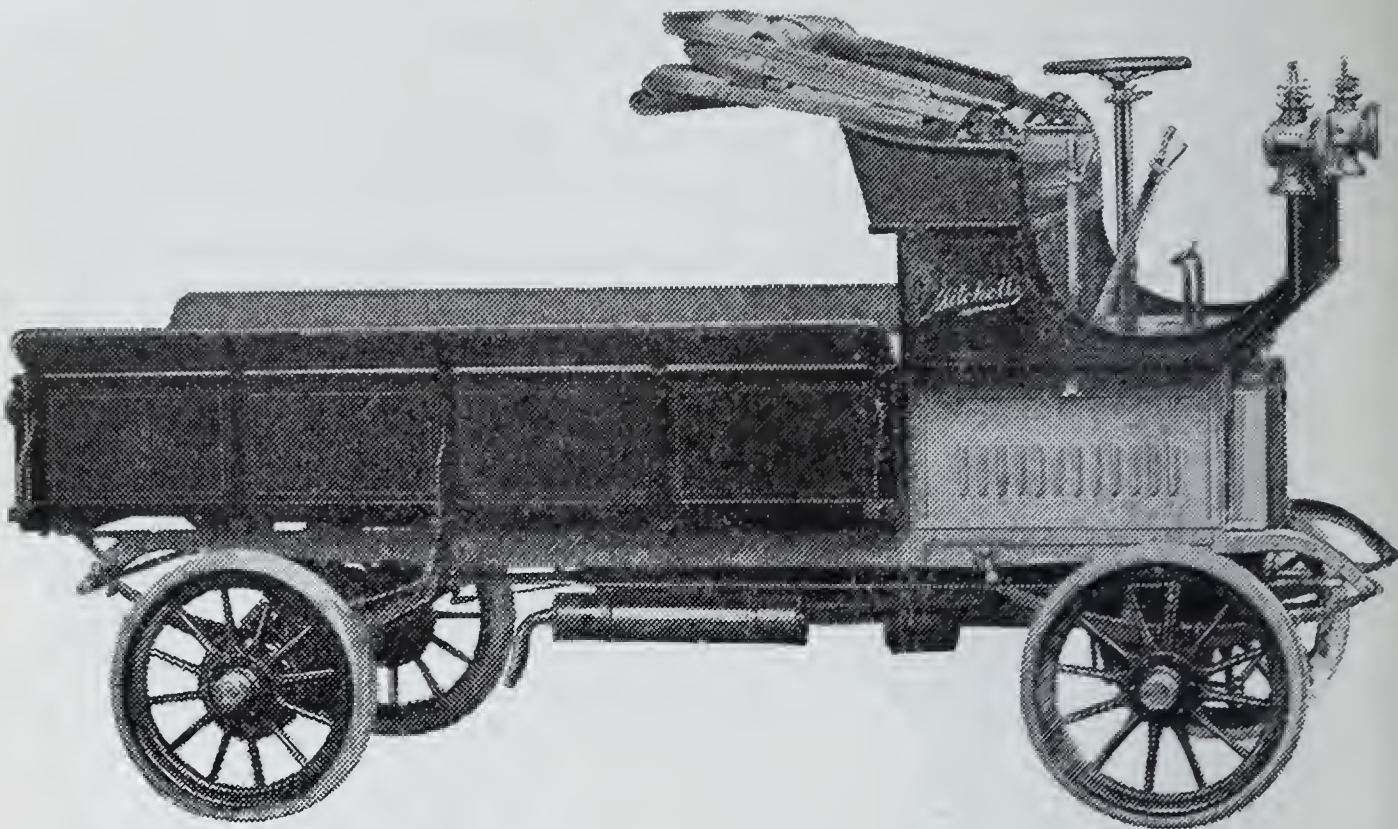


Fig. 21. Mitchell Gasoline Truck

The abundance of raw material and skilled labor make Pittsburgh a desirable location for a commercial automobile plant. In addition there is probably no city in the country where commercial car requirements can be so thoroughly tested in actual service, and it can be said with all assurance that a commercial vehicle developed in Pittsburgh and tried out on Pittsburgh hills and streets, and which is locally suc-

Fig. 22. Holsman Gasoline Delivery Wagon

cessful, could be shipped to any part of the world on a strong guarantee.

To those engaging in public service operation for passenger and freight service, the opportunities are equally alluring. The first requirement for such an opening is that a road should be available; second, that vehicles of real commercial efficiency should be placed upon that road; third, that these vehicles should be of sufficient number to justify the employment of experts to look after them, and to provide ample relays for the service; and finally that the business should be run on such principles as would be required for the success of any business, with ample capital and in a business-like manner.

PROPHESIES OF THE COMING TYPES

Gasoline Cars: Two-cycle, air cooled engine; four-wheel drive; friction transmission, or fluid transmission.

Steam Cars: Four-wheel drive with separate engine for each axle, or possibly separate engines for each wheel. Water tube boilers, using coke as fuel.

Electric Cars: Four-wheel drive with motor for each wheel.

DISCUSSION

Mr. W. G. Wilkins: I have been very much interested in listening to Mr. Macfarren's paper, especially that part of it referring to the possibility of automobiles in competition with trolley cars. I know of only two cities where automobile busses are regularly in use on fixed routes for passenger traffic, London, England and New York City. In neither of these cities can the automobile busses be said to come in direct competition with the trolley cars, as they are not run on the same streets. I suppose they are commercially successful or they would not continue in business. I do, however, have some doubts as to their being a success in Pittsburgh where they would be operated in direct competition with the cars of the Pittsburgh Railways Company, as they would have to run on the same streets. In the first place, the character of

the streets, both as regards the kind of pavements, and the grades are not favorable to heavy automobile traffic, and in the second place the streets are so narrow that automobiles would be confined to the narrow roadway between the curb and car track, and would be held up very frequently by slow moving horse vehicles. For these and other reasons, it is questionable in my mind, whether they would prove a commercial success in this city.

I do believe, however, that there might be a field for them in interurban traffic between small towns, where the traffic would not be large enough to warrant the expense required to build electric trolley roads; or between small towns situated a few miles from railroad stations, where they might replace the present stages that are now used.

Mr. J. A. Smith: We are running stage lines in New York, but the matter of their commercial success could not very well be attributes to any economy in gasoline transportation, as they are controlled by the magnates who control the Metropolitan Street Railway Company. I am of the opinion that there is a wide field for the commercial automobile if the industry is not gobbled up by the magnates of the present traction systems. The present stage of construction in gasoline engines has minimized the defects in ignition and transmission so that these troubles are very easily overcome, provided the companies are willing to employ competent men to run them, men who understand the automobile just as the locomotive engineer understands his mechanical apparatus.

There is great trouble with tire up-keep. There are certain points about rubber tires, and certain points about steel and wood tires, and we must take these different points conjunctively and figure them out. The rate per ton on a pneumatic tire, provided it is kept in proper position and properly inflated, is, I think, equal to the minimum of any solid tire. But you must take into consideration that economizing on tires costs in wear and tear on the car by vibration. At present we are in an experimental stage in commercial truck construction. We have passed that stage in the pleasure car

and the next few years will undoubtedly witness the construction of a substantial, economical commercial truck.

Mr. L. P. Blum: Mr. Macfarren has given us some figures on the cost of running forty autos in direct competition with trolley cars. As I understood his figures it would be necessary on a 5c basis for those forty autos to average 43 percent of their total load in order to be a paying investment. If this is correct, the figures fall by themselves, for no system of trolley traffic ever approaches a minimum of 43 percent of what the traffic men call the peak load.

On the question of freight transportation I believe he quotes a figure of 18c per ton-mile. While I am not acquainted with the figures of steam railroad costs yet I think 9c a mile would be considered something extravagant.

Mr. W. W. Macfarren: Referring to Mr. Wilkins' remarks, the grades of our streets are no more against the automobile than they are against the street car. This is a matter of power only, and the power can be at least as cheaply generated on the bus by an internal combustion engine as it can be generated by steam power, put through two electrical transformations and transmitted several miles.

While our pavements are in many cases not what they should be this is not universally so, and we may reasonably expect some improvement in this direction. A route from down-town to the East End can be selected over which the pavements are almost uniformly good, and the same is more or less true of routes to Allegheny. This consideration, however, is only local.

It is perfectly practicable, with suitable auto busses to beat almost any street car schedule now operating in Pittsburgh and *not run as fast at any time as the highest speed of the cars.* The reason is simple. The bus need not have as many stops to make for passengers nor is it delayed by preceding cars, as it can run around them. It is perfectly feasible to have alternate machines make different stops which cannot be done by cars operating on a fixed track.

The auto busses would by no means be confined to the

space between the curb and the car tracks as they have equal rights on the car tracks with horse vehicles; and, in many cases, due to their greater speed over horse vehicles, they could swing clear over to the opposite side of the street. An auto bus can get through the other traffic with *greater facility than any other form of passenger carrying car.*

I think that Mr. Smith is wrong in advocating high-priced men for running commercial cars. Motormen having several years street car service are the ones I would select if running a passenger auto service. An operator should not be expected to do repair work, nor does it pay to have him do so. The cars should be simplified to an extent such that a good motorman or a good horse driver would be amply competent to operate them.

Mr. Blum evidently misunderstood me somewhat. My figures show, if correct, that the busses would pay operating expenses if they averaged 43% of their seating capacity, *on a 5c fare for a five-mile haul.* Such a service in direct competition with a street car line *would not need to run at all* at times when there was not over 50% of seating capacity to be carried. But anyone who tries to start an auto bus service at 1c per passenger mile on such streets as we have in this city had better quit before he starts. A much higher fare can be obtained.

As to freight service, Mr. Blum misquotes me. I gave an estimate of 14¾c or 7⅜c per ton mile (loaded one or both ways) for a three-ton truck, and 11.4c or 5.7c per ton mile (loaded one or both ways) for a five-ton truck. The operating cost for a three-ton truck per *vehicle mile* is estimated at 22c.

The P. R. R. freight rate, first-class freight, from Pittsburgh to Monongahela City is 15c per hundred, any quantity. The distance is something less than 35 miles. Assuming that three tons of groceries were to be taken from Pittsburgh and that an equal load could be obtained on the return trip, the railroad rate one way is $9.00 or $18.00 both ways against $15.40, the cost of auto transit, showing a saving by the auto of $2.60 in addition to loading and unloading and drayage at terminals, which would probably amount to as much more.

Mr. R. C. McAteer: We are in the mercantile business and are running a truck built after our own design. While our experience has not been very large, we have found a good deal in favor of the truck for hauling merchandise. We have found two important drawbacks however to the really successful operation. One is the condition of the Pittsburgh streets, not necessarily the hills but the roughness, street car tracks, frogs, etc. The second is the expense of tires. Our greatest trouble has been tire up-keep on account of running into ruts and street car tracks and crossings. We have found the ideal conditions for a commercial truck are long hauls, a good large load and good roads. We have hauled four tons on a truck only designed for three, and have found that the extra wear makes that practice not worth while. But with a three-ton load and a long haul we can make money. Not that it is a big money maker, but it is satisfactory from a commercial standpoint. It costs us $8 to $9 a day, figuring depreciation and maintenance cost and two men on the truck. We do not try to use it for short hauls, but we do use it for the Wabash Terminal, Duquesne, Wilkinsburg, Edgewood, Swissvale, Crafton, Bellevue and places like those. I have recent reports showing that the truck does in one day more than any two teams would do in any one day.

There is a large field open for a light truck, one that will haul say 1,000 lbs., in the retail trade. We have probably fifty retail grocers on our books today who have the money and are ready to buy, whenever they can get it. But such a truck is not on the market yet.

Mr. H. S. Prichard: Steam railway companies own a very large, and electric railway companies a considerable, proportion of the property over which they run, and their tracks have to be maintained by themselves, but automobile companies escape the cost of such ownership and maintenance and this fact is mentioned as one of their commercial advantages in comparison with steam and electric railway companies. This is not an advantage justified by physical conditions. Automobiles need property and a prepared way on

which to run just as certainly as do cars and locomotives and just as certainly they cause wear and tear; probably to a greater extent per passenger or ton mile. The difference is that at present the public furnishes and maintains, free of cost to transportation companies, automobile but not rail "ways." It is reasonable to suppose, however, if automobile transportation companies are instituted to any considerable extent, that sooner or later they will be compelled to pay a fair compensation for the use, wear and tear of the public highways.

Mr. S. M. Kintner: It seems to be assumed that the jerking is an inherent defect of the trolley car. I think the same characteristic can be very easily shown in the automobile, and the existence of the gaso-electric drive in order to get smoothness of operation and flexibility of control is a very good evidence of the fact that the electric feature is not at fault in any way for the jerkiness that may be produced in a car. It is perfectly feasible, and a thing that has been in use on a number of electric roads, to have automatic accelerating control, in which the motorman simply turns on the lever and the automatics do the rest, and the acelerating is perfectly uniform from the time of the starting until maximum speed is reached. I think we are apt to get our ideas of these faulty features from the personnel of the operators of these various devices.

One point that was made I would like to emphasize a little, and that is the condition of our streets. I would like to know why we must have little squares cut in the asphalt just about the time the street is repaved and put in good condition, and then those holes filled with brick or left four or five inches below the general level of the street. When you come to increasing the schedule speed over streets of that kind above what the trolley car can make, you will find more jerks up and down than there are longitudinally on the trolley.

Mr. H. W. Fisher: Mr. Macfarren's paper is certainly a compendium of useful data relative to automobiles and I am sure it will be invaluable where reference is made to this subject. I would like to ask Mr. Macfarren to state in a few

words, along which lines future developments will be made; in what way will the coming trucks be improved?

Mr. W. W. Macfarren: I think that if Mr. McAteer is saving money with a truck which is the first one built from a new design, he is to be congratulated.

I am entirely at variance with Mr. Pritchard's statements about taxing the auto for direct maintenance of the roads. All horse vehicles and all autos are at present subjected to a city tax.

The owner of a horse-drawn vehicle or of any number of vehicles would have a perfect right to haul passengers to and from the city if he could secure their patronage.

It is, of course, fair that every user of the highways should pay for the privilege, but the tax should be based on the measure of use of the highways and not on the fact of competition with favored corporations.

The man who hauls a ton of passengers a mile over the streets does not in equity owe the city any more than the man who hauls a ton of iron or coal the same distance, and any tax based on any other method of reasoning would be discriminating. If anything, the auto bus man should be favored, as he is offering a direct accommodation to the public, not offered by the private vehicle.

In answer to Mr. Kintner, I have had some street railway experience, and have run a car myself, and therefore realize that most of the jerks on the trolley cars are due to the motorman's carelessness or desire to keep on time. However, if an auto bus became behind time, it would not be absolutely necessary to make up the time, as the machine is not delaying succeeding machines, as a late car would do. I do not advocate exceeding street car schedules with competing auto buses. I merely said that on crowded streets a bus could make a better schedule between terminals on account of not being delayed by the traffic, without having to run as fast as the maximum speed of the street car. This is merely from the fact that it can keep going nearly all the time.

Answering Mr. Fischer's question, I believe that the first

thing to be done to make the Commercial Car competitively efficient is to throw away the rubber tires. It does not make any difference what this change would cost at first, if the rubber can be finally successfully eliminated. In my opinion, it is essential to get rid of the rubber, and the way to get rid of it is to get rid of it, and then to strengthen the working parts of the car, if necessary, so they will stand the extra jars.

I do not think the four-cycle engine, with its complicated valve system is suitable for commercial cars. Several manufacturers are now putting two-cycle engines on their cars, and some of them are air cooled.

I think the large wheels are coming, and I think the friction drive will be largely used, especially on small cars. In large cars it is somewhat difficult to transmit the necessary amount of power in the available space, and in such cases, gaso-electric, gaso-hydraulic, and gaso-pneumatic combinations such as I have discussed will probably be used.

Mr. G. W. Knotts: As the principal cost of operation of Auto Trucks is maintenance, the most important feature of design should be simplicity This is not as feasible with a four-wheel drive as with only two wheels driven or rather with the driving wheels not steerable. I refer to well-known methods of transmitting power to vehicles. The principal advantage of driving all four wheels is to have better tractive power without an abnormal distribution of load upon the road bed. For ordinary street conditions, and in Pittsburgh, this is exceptionally bad, a two-wheel drive would fulfill all purposes.

While there is an advantage in steering all four wheels, I believe it is proven unnecessary by the thousands of motor driven vehicles now in use. Therefore, I do not see the necessity of complicating a machine in this way, which, in order to be a commercial success, must be put in the hands of unintelligent labor.

The means of power transmission suggested in this truck is entirely new to me. I have always considered the use of compressed air for the transmission of power as extravagant, though I am not familiar with its use except for small units;

such as, portable drills and hammers, and though considerable thought and money have been expended on the development of these tools, they are still very wasteful and liable to disorder. It is questionable whether the cost of up-keep of these air motors and compressors, together with the storage tanks and flexible air connections, would be less than a change gear device with clutch, etc., such as now used, and the larger engine necessary.

There is undoubtedly a great advantage in having a reserve power stored, ready for use in case of emergency, as this avoids the necessity of an engine or prime power unit of maximum power which would be very inefficient 90 percent of the time. This may offset what appears to be the complications of air drive, not so much its inefficiency with regards to fuel as its up-keep, for, unless the power unit and transmission is abnormally large, there are, I believe, many times when it would be strained to the breaking point, consequently increasing repair bills, and the question of repair bills is the "Bugaboo" of the motorist of today, buying gasoline and oil do not worry him.

In observing the ordinary horse-drawn wagons for rough freight of today, we find a total absence of springs and it appears, therefore, that springs on motor trucks are only necessary on account of the power plant.

I think that this is not the case, as it is evident that if loads on wagons were properly supported on springs, there would be less broken axles and wheels and fewer parts coming loose. The cost of springs would be less than the cost of repairs they would save. I have used an automobile for a number of years, (I had better say automobiles for one automobile does not last a number of years), driving daily over our roughest streets, and know the value of springs, not alone to my anatomy but to the machine. Most of this rough street driving is done with a single passenger, consequently the springs are only loaded to about one-quarter of what they are designed for, and I find it necessary to be constantly making adjustment, not alone to the engine and transmission, but the wheels, axles, and entire car. The spring suspension shown

in this truck may seem elaborate for a truck, but I believe it will undoubtedly reduce the cost of repairs more than enough to pay its cost and if all four wheels are to be driven, it is essential that each wheel carries its load at all times, regardless of the condition of road.

I do not take part in the discussion of this paper with any authoritive knowledge on the subject other than to know that a motor driven truck that will compete with the horse is a necessity.

Mr. W. W. Macfarren: Mr. Knotts' discussion of mechanical points is most welcome. I will admit that a two-wheel drive will fulfill all purposes in Pittsburgh, for nine months of the year, but maintain that the extra first cost of the four-wheel drive will be paid for by additional reliability and safety from accidents during the three winter months.

The advantage of four-wheel steering will become more apparent as our streets become more crowded. For the operator, it is just as easy to steer four wheels as two, and we must allow some intelligence in the maintenance man. Steering the rear wheels of the author's truck may be omitted, if desired, while still retaining the four-wheel drive.

It is true, as Mr. Knotts says, that compressed air transmission is usually extravagant, and this is especially true for the small units he mentions. They are very wasteful because they use cold air, and they are liable to disorder because they are made as light as possible to facilitate handling.

The weight of motors used for trucks could be proportionally greater than for air tools, and still be much lighter than any other form of motor, particularly electric. A glance at Figs. 11 and 12 will show that the air compressor and air motors designed for this truck are in a class by themselves as regards simplicity.

The motors of the gaso-pneumatic truck may be designed to slip the wheels at the maximum air pressure, which at once limits the maximum strain which can be placed on the transmitting elements, in addition to which this pressure is elastic.

as compared with the jerks attainable with a gear and clutch transmission.

When an engine and transmission, with power sufficient for maximum needs, is provided; in addition to the low fuel efficiency due to running much of the time at less than normal loads, the operating expenses are increased by the greater fixed charges due to increased cost of engine and transmission, and the load carrying capacity is correspondingly decreased by the excess weight of these parts.

I believe that the gaso-pneumatic truck can be designed to be lighter for a given service than any other form of automobile, because its power plant operates practically against an average load, similar to the operation of a street railway power house.

[The Editor desires to acknowledge the courtesy of The Scientific American, The Automobile Trade Journal and others for cuts furnished.]

CONTRACTS, WITH SPECIAL RELATION TO STRUCTURAL STEEL WORK

MR. J. A. MCEWEN:* The outline and forms herewith submitted are not given as a learned and logical discussion of the subject, but rather as a basis of discussion, the various items and topics being arranged with this end in view. We might mention briefly a few of the essential things which go to make up a contract in order to get a comprehensive view of the subject.

There must be a legal subject on which to base our contract, i. e., material to furnish or work to perform or both; our present discussion having to do mainly with the furnishing and erecting of structural steel buildings.

There must be at least two parties; the one usually designated the Contractor, who furnishes the material and performs the work, and the other the Owner or Purchaser (I prefer the latter term), for whom the material is furnished and work done. There is usually a third party, the Engineer or Architect, who performs a very important function in the execution of a contract, but whose duties will be taken up under a separate head.

There must be a legal mutual agreement between two parties to form a contract. This agreement is usually reached by an offer by one party and an acceptance by the other.

The work to be done is usually based on drawings, specifications, or both; furnished by the purchaser, contractor or by a third party, the engineer or architect.

The work done must be for a consideration and the terms of payment must be mutually agreed upon.

The work is usually done under the superintendence of an engineer or architect. The conditions governing this supervision should be specified in the contract.

The time of completion is usually an important consideration, and if so, should be arranged in the contract.

* Assistant Engineer, Pittsburgh Bridge and Iron Works, Rochester, Pa.

If the work is to be inspected at the shop or mill, or both, the conditions governing this inspection should be stipulated in the contract, or specifications.

If changes or complications are liable to occur as the work progresses, provision may be made to submit to arbitration differences which may arise.

As the conditions at the site of the building are a fruitful source of controversy, there should be a mutual understanding as to the rights and privileges of all parties during the erection of the work.

In important work it is usually well to provide for delays, avoidable or unavoidable, occasioned by either party.

There are innumerable forms of contracts, but as a further basis for discussion, we submit the following types of contract forms, the simplest form being a proposition and acceptance or a requisition based on the proposition. This will answer the purpose in all ordinary work when the parties are at all disposed to be fair. It usually precedes the signing of a formal contract in any case and should be carefully considered.

The Central Construction Company,
Pittsburgh, Pa., Aug. 12, 1909.

The Federal Mfg. Co., Pittsburgh, Pa.

Gentlemen:

Answering your inquiry of August 5th, for quotation on steel building 60 ft. 0 in., by 150 ft. 0 in., we quote you Five Thousand ($5 000.00) Dollars for furnishing and erecting this building on foundations prepared by you.

We include the furnishing and erecting of a complete building above foundations; i. e., the steel frame, roofing, siding, windows and doors; all as per plans and specifications of the Modern Engineering Company, accompanying your inquiry.

We do not include any gutters or down spouts, none being shown on plans.

All material to be painted one coat before shipment and one after erection, as per specifications. Anchor bolts to be furnished by us and set by purchaser. Material and workmanship to be according to Manufacturers' Standard, Specifications for Structural Steel*.

The terms of payment to be fifty (50) percent of the contract price upon presentation of Bill of Lading showing complete shipment

* This clause is only used in the absence of specifications or where they do not cover this portion of the work.

of the material, thirty (30) percent when the erection is completed and twenty (20) percent thirty days after completion of erection.

It is understood that the material can be unloaded from a railroad siding at the site of the building and that the site will be clear for the erection of the work.

This quotation is submitted on condition of prompt acceptance. The work to be completed in 90 days from the date of acceptance of this proposition. Yours truly,

The Central Construction Company,
John Doe, President.

Accepted Aug. 20, 1909,
By The Federal Mfg. Co.,
John Smith, President.

This proposition may be written in duplicate and accepted as noted above, or a letter accepting the proposition will make a binding contract.

Type II

This type is a very complete formal contract, and has been made with special reference to structural steel work.

This agreement made in duplicate and concluded this .... day of ...., 19...., by and between the.................. ...., a corporation of the State of Pennsylvania, party of the first part (called the Contractor), and ...., party of the second part (called the Owner),

Witnesseth that for and in consideration of the mutual promises hereinafter stated, the parties do agree as follows:

Article I. The Contractor will furnish—and erect in place or F. O. B. cars—.., located at ...., as shown on plans and described in specifications of ....—Engineer or Architect.—The drawings referred to being Nos. ...., dated ...., and the specifications covering pages Nos. ...., dated .... These drawings and specifications hereby becoming a part of this contract.

Article II. The —Architect or Engineer—shall furnish all necessary additional detail drawings to make the work clear, which drawings shall not be inconsistent with the original drawings and specifications referred to above.

Article III. No alterations shall be made in the work, except upon the written order of the Owner; and the amount to be paid by the Owner, or allowed by the Contractor, because of these alter-

ations, shall upon mutual agreement be stated in the order. Should the Owner and the Contractor not agree as to this amount, the work shall go on under the order, but the amount to be paid or allowed shall be fixed by arbitration provided for in this contract.

Article IV. If called for in the specifications, the Contractor shall provide, at such times and places as will least interfere with his operations, facilities for the inspection of the work by the Owner; but the Owner agrees that the Contractor shall not be liable for any injuries sustained by the inspectors. Any material condemned shall be removed upon written notice and replaced by other and suitable material.

Article V. Should the Contractor at any time refuse or neglect to supply enough workmen of proper skill or materials of proper quality, or to carry on the work with promptness and diligence, the Owner, if not at fault, may give the Contractor thirty (30) days written notice, and at the end of that time if the Contractor continues to neglect the work, the Owner may provide such labor or materials and deduct the cost from any money due or to become due the Contractor under this contract, or may terminate the employment of the Contractor under this agreement and take possession of the premises and employ any other person or persons to finish the work. In the latter case, the Contractor shall receive no further payment until the work shall be finished; then if the unpaid balance that would be due under this contract exceeds the cost to the owner of finishing the work, such excess shall be paid to the Contractor.

Article VI. If for more than one (1) month at any time, any act or neglect of the Owner or any legal proceeding taken against him, prevents the starting or continuous prosecution of the work, the Contractor may give the Owner ten (10) days written notice, and at the end of that time if the Owner continues at fault or the legal proceeding continues effective, the Contractor may terminate his obligations under this contract; in which case the Owner shall at once pay the Contractor for the labor and materials already furnished and all damages the Contractor may sustain.

Article VII. The Contractor will—complete or ship—the several sections or the whole of the work on or before the following date, ..., 19.., provided all the necessary data is furnished within five (5) days after the signing of this agreement, and the foundations for the structure are completed so that no delay may be occasioned from this cause, and that all lines and levels and all labor and materials to be furnished by the Owner and other contractors are furnished in such time and manner as not to delay the Contractor; and provided further, that there are no delays due to transportation, strikes, fires, floods, storms, or any other circum-

stances beyond the Contractor's reasonable control. Should the work be delayed by any of the above causes, the Contractor will complete his work in a reasonable time under all the circumstances.

Article VIII. The Owner will pay the Contractor the sum of .... ($————), in current funds as follows:

Fifty percent (50%) of the contract price of all material shipped plus 35% of the contract price of all material erected during each month shall become due and payable on the 10th day of the succeeding month; the remaining fifteen percent (15%) shall become due and payable 30 days after the completion of the work, or of each section of the work included in the contract. Should the Contractor be delayed on the work, or any part thereof, in any manner not due to his own neglect, for a time exceeding 30 days, eighty-five percent (85%) of the cost of all material prepared and the labor performed affected by said delay, shall immediately become due and payable. For work delivered only eighty percent (80%) of the contract price of material shipped each month shall become due and payable on the 10th day of the succeeding month and the balance of contract price on the work or each section thereof shall be paid in 30 days after shipment.

Failure by the Owner to make payments at the times provided in this contract shall give the Contractor the right to suspend work until payment is made, or at his option, after thirty (30) days' notice in writing, should the Owner continue in default, to terminate this contract and recover the price of all work done and materials provided and all damages sustained, and such failure to make payments at the times provided shall be a bar to any claim by the Owner against the Contractor for delay in completion of the work.

Article IX. The Contractor will indemnify and save harmless the Owner from all claims and costs arising from any damage to persons or property occurring in the performance of this contract and due to negligence of employees or agents of the Contractor.

Article X. The work shall be inspected for acceptance by the Owner immediately upon receipt of notice that the work is ready for inspection and the final payment shall be conclusive evidence of the performance of this contract.

Article XI. Any difference or dispute arising between the Owner and the Contractor shall be referred to three (3) disinterested arbitrators, one to be appointed by each of the parties to this contract and the third by the two thus chosen; the decision of any two shall be final and binding and each of the parties shall pay one-half of the expense of such reference.

Article XII. The Owner shall maintain during the progress of the work full insurance on the work, in his own name and in the

name of the Contractor, against loss or damage by fire. The policies shall cover all work incorporated in the building, and all materials for the same in or about the premises, and shall be made payable to the parties as their interests may appear.

In witness whereof, the parties have duly executed this agreement as of the date first given.

Attest:

By....................................

.... [Seal]

.... [Seal]

Type III

This form, known as the "Uniform Contract," has been adopted and recommended for general use by the American Institute of Architects and National Association of Builders. It has been arranged for general contracting work and is hardly suited to structural steel work.

In general, contracts should be clear, specific and equitable to all parties. In the "Uniform Contract" the architect is made sole arbiter, unless his decision is rejected and the matter goes to a board of arbitration. The architect being employed by the owner, makes the matter very much one sided. Government contracts are possibly the most unfair of all forms, because the contractor is entirely at the mercy of the government.

This agreement, made the .... day of .... in the year one thousand nine hundred and ...... by and between ...., party of the first part (hereinafter designated the Contractor), and .... party of the second part (hereinafter designated the Owner).

Witnesseth, that the Contractor, in consideration of the agreements herein made by the Owner, agrees with the said Owner as follows:

Article I. The Contractor shall and will provide all the materials and perform all the work for the ...., as shown on the drawings and described in the specifications prepared by .... Architect, which drawings and specifications are identified by the signatures of the parties hereto, and become hereby a part of this contract.

Art. II. It is understood and agreed by and between the parties hereto that the work included in this contract is to be done under the direction of the said Architect, and that his decision as to the true construction and meaning of the drawings and specifications shall be final. It is also understood and agreed by and between the parties hereto that such additional drawings and explanations as may be necessary to detail and illustrate the work to be done are to be furnished by said Architect, and they agree to conform to and abide by the same so far as they may be consistent with the purpose and intent of the original drawings and specifications referred to in Art. I.

It is further understood and agreed by the parties hereto that any and all drawings and specifications prepared for the purposes of this contract by the said Architect are and remain his property, and that all charges for the use of the same, and for the services of said Architect, are to be paid by the said Owner.

Art. III. No alterations shall be made in the work except upon written order of the Architect; the amount to be paid by the Owner or allowed by the Contractor by virtue of such alterations to be stated in said order. Should the Owner and Contractor not agree as to amount to be paid or allowed, the work shall go on under the order required above, and in case of failure to agree, the determination of said amount shall be referred to arbitration, as provided for in Art. XII of this contract.

Art. IV. The Contractor shall provide sufficient, safe and proper facilities at all times for the inspection of the work by the Architect or his authorized representatives; shall, within twenty-four hours after receiving written notice from the Architect to that effect, proceed to remove from the grounds or buildings all materials condemned by him whether worked or unworked, and to take down all portions of the work which the Architect shall by like written notice condemn as unsound or improper, or as in any way failing to conform to the drawings and specifications, and shall make good all work damaged or destroyed thereby.

Art. V. Should the Contractor at any time refuse or neglect to supply a sufficiency of properly skilled workmen, or of materials of the proper quality, or fail in any respect to prosecute the work with promptness and diligence, or fail in the performance of any of the agreements herein contained, such refusal, neglect or failure being certified by the Architect, the Owner shall be at liberty, after three days written notice to the Contractor, to provide any such labor or materials, and to deduct the cost thereof from any money then due or thereafter to become due to the Contractor under this contract; and if the Architect shall certify that such refusal, neglect or failure is sufficient ground for such action, the Owner shall also

be at liberty to terminate the employment of the Contractor for the said work and to enter upon the premises and take possession, for the purpose of completing the work included under this contract, of all materials, tools and appliances thereon, and to employ any other person or persons to finish the work, and to provide the materials therefor; and in case of such discontinuance of the employment of the Contractor .... shall not be entitled to receive any further payment under this contract until the said work shall be wholly finished, at which time, if the unpaid balance of the amount to be paid under this contract shall exceed the expense incurred by the Owner in finishing the work, such excess shall be paid by the Owner to the Contractor; but if such expense shall exceed such unpaid balance, the Contractor shall pay the difference to the Owner. The expense incurred by the Owner as herein provided, either for furnishing materials or for finishing the work, and any damage incurred through such default, shall be audited and certified by the Architect, whose certificate thereof shall be conclusive upon the parties.

Art. VI. The Contractor shall complete the several portions, and the whole of the work comprehended in this Agreement by and at the time or times hereinafter stated, to wit:

....

Art. VII. Should the Contractor be delayed in the prosecution or completion of the work by the act, neglect or default of the Owner, of the Architect, or of any other contractor employed by the Owner upon the work, or by any damage caused by fire or other casualty for which the Contractor .... not responsible, or by combined action of workmen in no wise caused by or resulting from default or collusion on the part of the Contractor, then the time herein fixed for the completion of the work shall be extended for a period equivalent to the time lost by reason of any or all the causes aforesaid, which extended period shall be determined and fixed by the Architect; but no such allowance shall be made unless a claim therefor is presented in writing to the Architect within forty-eight hours of the occurrence of such delay.

Art. VIII. The Owner agrees to provide all labor and materials essential to the conduct of this work not included in this contract in such manner as not to delay its progress, and in the event of failure so to do, thereby causing loss to the Contractor, agrees that .... will reimburse the Contractor for such loss; and the Contractor agrees that if .... shall delay the progress of the work so as to cause loss for which the Owner shall become liable, then .... shall reimburse the Owner for such loss. Should the Owner and Contractor fail to agree as to the amount of loss comprehended in this Article, the determination of the amount shall be referred

to arbitration as provided in Art. XII of this contract.

Art. IX. It is hereby mutually agreed between the parties hereto that the sum to be paid by the Owner to the Contractor for said work and materials shall be ....
subject to additions and deductions as hereinbefore provided, and that such sum shall be paid by the Owner to the Contractor, in current funds, and only upon certificates of the Architect, as follows:

....

The final payment shall be made within .... days after the completion of the work included in this contract, and all payments shall be due when certificates for the same are issued.

If at any time there shall be evidence of any lien or claim for which, if established, the Owner of the said premises might become liable, and which is chargeable to the Contractor, the Owner shall have the right to retain out of any payment then due or thereafter to become due an amount sufficient to completely indemnify .... against such lien or claim. Should there prove to be any such claim after all payments are made, the Contractor shall refund to the Owner all moneys that the latter may be compelled to pay in discharging any lien on said premises made obligatory in consequence of the Contractor's default.

Art. X. It is further mutually agreed between the parties hereto that no certificate given or payment made under this contract, except the final certificate or final payment, shall be conclusive evidence of the performance of this contract, either wholly or in part, and that no payment shall be construed to be an acceptance of defective work or improper materials.

Art. XI. The Owner shall during the progress of the work maintain insurance on the same against loss or damage by fire, ... the policies to cover all work incorporated in the building, and all materials for the same in or about the premises, and to be made payable to the parties hereto, as their interest may appear.

Art. XII. In case the Owner and Contractor fail to agree in relation to matters of payment, allowance or loss referred to in Arts. III or VIII of this contract, or should either of them dissent from the decision of the Architect referred to in Art. VII of this contract, which dissent shall have been filed in writing with the Architect within ten days of the announcement of such decision, then the matter shall be referred to a Board of Arbitration to consist of one person selected by the Owner, and one person selected by the Contractor, these two to select a third. The decision of any two of this Board shall be final and binding on both parties hereto. Each party hereto shall pay one-half of the expense of such reference.

....

The said parties for themselves, their heirs, successors, executors, administrators and assigns, do hereby agree to the full performance of the covenants herein contained.

IN WITNESS WHEREOF, the parties to these presents have hereunto set their hands and seals, the day and year first above written.

In presence of ....

PENALTIES AND BUSINESS DAMAGES FOR FAILURE TO COMPLETE WORK UNDER CONTRACTS

MR. W. B. ADAIR:* The topic assigned to me was subdivided by Mr. McEwen into three heads:

First—Liabilities of parties for uncompleted contracts.

Second—Penalties and bonuses as related to time of completion.

Third—Damages for failure to complete on time, due to negligence of contractor or hindrance by owner.

The first head covers instances where the contractor never completes the job, the other heads treat of the time of completion.

Let it be supposed that a contractor has entered into the performance of a building contract and for some reason, without legal excuse, leaves the work uncompleted. Litigation may follow in either one of two ways. The contractor may attempt to recover for the work actually done, or the owner may sue for damages.

Ordinarily a building contract is entire, not severable; that is, the contractor undertakes the work as one job and not as a plurality of distinct and separate pieces of work; and until the contractor can show that the job is done he cannot demand his pay. Of course, if the contract provides for payments to be made at certain stages of the work, the installments can be sued for as each becomes due.[1] But where the money, or the unpaid balance of it, is payable only when the contract is performed, the contractor in order to recover must, as a general rule, show that he has performed his contract.

* Attorney, Farmers' Bank Building, Pittsburgh.

1 Crawford vs. McKinney, 165 Pa. 605 and 609.

It is not, however, always necessary to show an absolutely exact performance. If the contractor, honestly trying to perform his contract, does so substantially, he may recover notwithstanding trifling defects or omissions, for which the owner may be compensated.[2]

The question whether the contract has been substantially performed is usually left to the jury to determine from all the circumstances of the case. But the question will be decided by the judge against the contractor if the latter has wilfully omitted performance of even minor matters. As was said by our Supreme Court: "The equitable doctrine of substantial performance is intended for the protection and relief of those who have faithfully and honestly endeavored to perform their contracts in all material and substantial particulars, so that their right to compensation may not be forfeited by reason of mere technical, inadvertant or unimportant omissions or defects. It is incumbent on him who invokes its protection to present a case in which there has been no wilful omission or departure from the terms of his contract. If he fails to do so, the question of substantial performance should not be submitted to the jury."[3]

The amount which the owner is entitled to deduct from the contract price in case of a substantial performance is generally the necessary cost of correcting the omissions or defects.

If the contractor abandons the work in an incomplete state without just cause, he cannot recover anything for what he may have done up to the time of the abandonment, and even if the owner uses the incomplete work and gets the benefit of it, it is doubtful whether he is required to pay anything for it, because as the structure is attached to his land he cannot help using it unless he either goes to the expense of tearing it away or abandons his land.[4]

But even if the contractor can sue on an uncompleted contract, the owner can deduct damages for the failure to

2 30 A. & E. Ency. Law 1221; Holmes v. Oil Co., 138 Pa. 546; Gallagher v. Sharpless, 134 Pa. 134.

3 Gillespie Tool Co. v. Wilson, 123 Pa. 19.

4 Wade v. Haycock, 25 Pa. 382; Hartupee v. Pittsburgh, 97 Pa. 107; Hartman v. Meighan, 171 Pa. 46.

complete; or, the contractor being in default, the owner can sue him for damages, and the measure of damages is, in the absence of any special agreement or unusual circumstances, the amount it would cost the owner to complete the job and the rental value of the premises for the time the completion of the building was delayed by the contractor's default.[5]

If the breach of contract is on the part of the owner, so that the contractor is prevented or excused from doing or completing the work, either by the refusal of the owner to permit him to do so or by the owner's default in some essential particular, the contractor can recover for what he has done, and damages for the breach of the contract by the owner, which would be the excess of the contract price of the work over what it would have cost the contractor to do the job.

The so-called Uniform Contract[6] provides that the owner, upon certificate of the architect and after notice to the contractor, may in certain cases take hold of the work and complete it and deduct the cost from the contract price, or if it exceeds the unpaid contract price may recover the difference. It has been held under this form of contract that if the job is completed by the owner the contractor can sue on the contract, alleging that it has been performed, and recover the contract price less the cost to the owner of what the latter did to complete the work.[7]

The next matters to be considered are penalties and bonuses with relation to time of completion. It may be remarked here that there is a belief among many building contractors that a penalty clause is not good unless there is also a bonus clause. This belief is wholly unfounded in law.

There is a great difference between the powers of parties to contract for bonuses and their power to contract for penalties. Parties can bind themselves to pay for work whatever prices they see fit, and to increase the price for early completion. But courts refuse to enforce penalties as such. All that the law gives an injured party to a contract is such dam-

5 Fire Association v. Rosenthal, 108 Pa. 474; Brown v. Foster, 51 Pa. 166.

6 For Uniform Contract see page 421.

7 Hunn v. Pa. Inst. for Instruction of Blind, 211 Pa. 403.

ages as will, as nearly as possible, put him in as good a plight as if the contract had not been broken, with this qualification, that speculative profits and damages such as the parties could not have supposed might be the consequences of a breach of the contract will not ordinarily be allowed. Where a breach of contract has already occurred the parties may of course settle their disputes by liquidating the damages at such figures as they may agree upon, and they furthermore may agree in advance upon a basis of liquidating the damages which may accrue in case of breach. But whether a sum named in a contract as compensation for its breach is to be regarded as a penalty, and therefore not enforceable, or as liquidated damages and therefore binding, is a difficult question often coming before the courts. The question was discussed in the following language by the late Chief Justice Paxson of the Pennsylvania Supreme Court:

"The intention of the parties has much to do with it. Yet even that will be controlled where equity demands it. A sum expressly stipulated as liquidated damages will be relieved from if it is obviously to secure a sum capable of being compensated by interest. It is difficult to lay down a general rule applicable to such cases, for the reason that each case as it arises is to be determined by its own particular facts, more than by a rule of general application. The nearest approach to a rule upon this subject is to be found in Streeper v. Williams[8] where it was said by Mr. Justice Agnew: 'Upon the whole, the only general observation we can make is, that in each case we must look at the language of the contract, the intention of the parties as gathered from its provisions, the subject of the contract, and its surroundings, the ease or difficulty of measuring the breach in damages, and the sum stipulated, and from the whole gather the view which good conscience and equity ought to take of the case.' And," continues Judge Paxson, "I will supplement these well-considered remarks by saying that where the damages are unconscionable and grossly disproportioned to the injury sustained, equity will generally relieve therefrom by treating the

8 48 Pa. 450.

sum as a penalty, for the reason that the parties to the contract probably regarded it as such when the contract was made."

In the case from which the above quotation is taken; the court refused to enforce a stipulation that the contractor should pay $150.00 per week for delay, when the evidence showed the rental value of the house was $25.00 a month and the total value of the house and lot was about $3000.00. The Chief Justice further said:

"The damages for the delay were easily ascertainable. They could be fixed approximately by the rental value of the property. When it is difficult or impossible to ascertain the damages by any fixed rule, for the breach of a contract, there is a reason for the parties to liquidate them in advance, and why the courts should hold them to such liquidation. But when the damages can be assessed almost as easily and accurately as in the case of a bond for the payment of money, and they are fixed by the contract itself at an unconscionable sum, it is the plain duty of a court exercising equity powers to relieve against such injustice, and treat the sum named as a penalty merely."

As an example of the enforcement of a stipulation for liquidated damages, the case of Malone v. Philadelphia[9] may be cited, where in a contract for building a bridge for a city of provision that the contractor should pay $50.00 per day for delay in completion was enforced by the court. It was pointed out that the city had paid $271 000.00 on the contract up to the time default occurred and interest on that sum would amount to a considerable part of the $50.00 per day; and also that what the public inconvenience would amount to in dollars and cents would be difficult, not to say impossible, to estimate. "This difficulty," said the court, "brings the stipulation within the well settled rule that it will be inferred that parties intended a sum agreed to be paid upon breach of a contract as liquidated damages, whenever the damages are uncertain and not capable of being ascertained by any satisfactory rule."

9 147 Pa. 416.

It is therefore necessary in drafting provisions for consequences of a breach of the contract, not to make the damages too great, lest the purpose be wholly defeated.

The difficulty about making an enforceable agreement as to damages is sometimes avoided by making the time of completion much later than the work is expected to be done, and allowing a bonus for each day, up to a certain maximum, before that date the work is completed. But such a provision would deprive the owner of any other remedy for delay beyond the date really intended—that is, he could not rescind the contract or put his own men at work.

The uniform contract makes no provision for liquidated damages or for bonus.

The next topic is damages for failure to complete on time, due to the negligence of contractor or hindrance by owner.

If the contractor, without fault of the owner, fails to complete his work on time, he is liable in damages. A promise to have work done by a particular month requires it to be done before that month[10]. If the contract does not specify the time for completion the law will construe it to require completion within a reasonable time to be determined, by the jury, from all the circumstances.

In the case of a contract requiring completion by a specified time, the question of the contractor's negligence or diligence is not considered, nor, in the absence of express provision, do strikes, accidents, delay in getting material, etc., afford any excuse. Possibly if the work were destroyed or injured by lightning, earthquake, or some other like unforseeable and unavoidable act of God, performance on time would be excused.

The measure of damages is such loss sustained by the owner as may be regarded as having been within the contemplation of the parties when the contract was made as likely to result from a breach. For example, in the case of erecting a mill, the damages will not be the profits which might have been made by operating the mill during the period of delay, because of the uncertainty there would be as to what

10 Rankin v. Woodworth, 3 P. & W. 48.

profits would have been earned; the rental value of the mill is regarded as a fairer measure of the contractor's liability.[11]

The failure of the contractor to complete the work within the agreed time will be excused if caused by the wrongful acts of the owner or by his neglect to do his part under the contract. The books furnish many illustrations. Thus, there is a good excuse where the delay is caused by the owner's refusal to permit the contractor to complete the work or by his direction of a suspension of the work; by the owner's failure to deliver timely possession of the premises upon which the work is to be done; by the failure of the owner to pay when due the installments of the compensation which were payable as the work progressed (if the contractor exercised his right to stop work until he was paid); by the failure of the owner to secure a building permit for the erection of the building or comply with the city building regulations; by the owner's failure to do certain work required on his part and necessary to be done before the contractor could do his work; by the failure of the owner to perform an agreement on his part to furnish the materials with which the contractor is to perform the work; by the failure of the owner to furnish plans and specifications in cases where it is his duty to furnish them[12] or by the failure of the owner or his architect to furnish lines and levels as required by the contract[13].

The owner's architect who supervises the work is the agent of the owner, and where the delay is caused by his wrongful acts, as through mistakes in the plans and specifications, requiring a part of the work to be done a second time, or by the architect's failure to deliver copies of the plans and specifications on time, the contractor is excused. Where the contractor's work cannot be done until the completion of other work for which the owner has contracted with a third person, delays caused by such third person's failure to perform his contract will excuse delay on the part of the contractor. But the owner and contractor may agree that the hindrance caused by other independent contractors shall not excuse

11 Rogers v. Bemus, 69 Pa. 432.
12 30 A. & E. Ency. L. 2d ed. 1255.
13 White v. School Dist., 159 Pa. 201.

delays unless notice of such hindrance is given by the contractor to the owner or his architect, and in such case unless the required notice is given the contractor cannot excuse his delay for such reason. The contractor is not as a general rule liable for delay in performance caused by extra work and alterations in the contract directed by the owner.[14]

The delay on the part of the contractor is excused, however, only to the extent it was caused by the acts or omissions of the owner or others, relied on as an excuse, and when the cause of delay is removed the contractor must, if he proceeds with the work, be diligent to complete it without further delay.[15]

LIABILITY FOR DAMAGES DURING CONSTRUCTION

MR. H. M. STILLEY:* The topic assigned to me is so comprehensive that a book might be written on it, and in the short time allowed it will be necessary to confine my remarks to general statements.

Each individual case arising under contracts ordinarily has some particular facts embodied therein which to a greater or lesser degree govern the liability of the contractor, subcontractor or owner.

If the party injured by negligence of the contractor is guilty of contributory negligence on his own part, that is, has negligently done something himself that has contributed in any degree to the injury, the contractor is relieved from liability.

In the absence then of contributory negligence on the part of the party injured, the owner, contractor or sub-contractor, as the case may be, is liable for injury caused by negligence, and this to persons or property lawfully on or off the premises.

Negligence is the absence of care under the circumstances.

That which is negligence in one case, by a change of circumstance, may become ordinary care in another; and that

14 30 A. & E. Ency. Law, 2d ed. 1256-1257.

15 30 A. & E. Ency. Law, 2d ed. 1256; Pittsburgh Iron & Steel Engineers Co. v. National Tube Works Co., 184 Pa. 251.

* Attorney, Frick Building, Pittsburgh.

which is ordinary care may become, under different circumstances, gross negligence.

The degree of care required is not what a man thinks necessary and proper, or such as an ordinary prudent man would exercise with full knowledge of the circumstances, but such care as a reasonable and prudent man would exercise under like circumstances.

Negligence, then, is ordinarily a question for the jury.

Proximate Cause

To entitle an injured party to recover for negligence, the negligence must be the proximate cause of the injury.

Proximate cause is not to be determined by time or distance, but by the succession of events; the question is whether there was any intermediate cause, disconnected from the primary fault and self-operating, which produced the injury; if there was not, the act of negligence must be considered as the proximate cause of all the consequences resulting therefrom.

The burden of proof is on the injured party to show that the defendant was guilty of negligence, and that such negligence caused the injury complained of. The mere fact of injury will not, in general, raise a presumption of negligence.

Master and Servant

A master is responsible for injuries occasioned to third persons by the negligence of a servant in the performance of his duty to his master, and within the scope of his employment.

Independent Contractors

The general rule is that the owner or occupant of property upon which work is done by another under contract, not as a servant but as a mechanic or contractor in an independent employment, is not liable for injuries to third persons resulting from the negligent performance of the work, when there is no want of due care in the selection of such contractor.

A stipulation in a contract for a general supervision of the work by the architect, engineer, or superintendent for the

employer is not such a reservation of control over the contractor as will suffice to shift his responsibility to the employer. The same is true of a reservation of the right to assume control of the work, should the contractor fail to finish it by a time specified. But if the employer reserves the right to control the manner of performing the details of the work, and to discharge any persons employed on the work, the contractor is not independent, and the employer is liable for injuries resulting from the negligence of the contractor.

Liability of Employer to Employees of Contractor

In the absence of negligence in the choice of a contractor, one employing an independent contractor is not answerable to a laborer employed by the contractor for injuries due to the contractor's negligence.

Liability of Contractors and Sub-Contractors

An independent contractor is liable for an injury to a third person due to negligence in the performance of the contract.

After an employer has accepted the work of an independent contractor, the contractor's liability to third persons, strangers to the contract, ceases and no recovery can be had against him for injuries to such persons due to the negligent manner in which his work was performed.

Sub-Contractor

An independent contractor may sublet his contract to another independent contractor upon such terms as to escape liability for the negligence of the latter, but the evidence must clearly show that the sub-contractor assumed entire charge and control of the work and did not stand in the relation of servant to the principal contractor.

That the sub-contractor agrees to indemnify the principal contractor for any damages which may result from the performance of the contract, does not alter the liability of the principal contractor to third persons.

An independent contractor employing a sub-contractor to do part of the work is bound to do his own part of the work

so as to render it safe for the employees of the sub-contractor acting within the scope of the employment.

Fellow Servants

The general rule is that all workmen in the same employment, whatever may be the extent of their association, are fellow servants, so that the negligence of one causing injury to another does not render the employer liable. This general rule has been greatly modified by the employer's liability act of 1907 which provides that in all actions brought to recover from an employer for injury suffered by his employe, the negligence of a fellow servant shall not be a defense, where the injury was caused or contributed to by any of the following causes:

Any defect in the works, plant or machinery of which the employer could have had knowledge by the exercise of ordinary care; the neglect of any person engaged as superintendent, manager, foreman, or any other person in charge or control of the works, plant or machinery; the negligence of any person in charge of or directing the particular work in which the employe was engaged at the time of the injury or death; the negligence of any person to whose orders the employe was bound to conform, and did conform, and by reason of his having conformed thereto, the injury or death resulted; the act of any fellow servant, done in obedience to the rules, instructions or orders given by the employer, or any other person who has authority to direct the doing of said act.

The manager, superintendent, foreman, or other person in charge or control of the works, or any part of the works, shall, under this act, be held as the agent of the employer in all suits for damages for death or injury suffered by employees.

THE ARBITRATION OF DISPUTES

MR. S. A. SCHREINER:* There are always two sides to every question—the right side and the wrong. The right side is the one that you have, and the wrong side is that of the other fellow. And if you catch the other man in a candid

* Attorney, Berger Building, Pittsburgh.

moment you will find that he thinks the same. The average dispute is well typified by the picture of three men and a cow. One man is pulling with might and main at its tail; the other is making equal efforts at her head, while the lawyer is industriously milking away during the excitement. It might be hard to tell which one had the better end of the cow, but rest assured that the lawyer was getting the most out of her.

This principle has become generally recognized and the result has been an effort, in the average contract, to secure an amicable settlement or arbitration of any disputed matters which may arise between the parties.

While the courts look with a jealous eye upon anything which may oust their jurisdiction, yet they distinctly favor arbitration. Within a few months in Allegheny County, a special court of arbitration presided over by picked members of the bar has been organized for the purpose of clearing from the docket the accumulation of minor cases. Many times the lower and supreme courts of this State have upheld the award of a board of arbitrators chosen by the parties to a contract for the settlement of matters in dispute.

It is the policy of the law that an end be made to litigation (to quote the Latin proverb), and for this reason arbitration is favored. But it is also the policy and especial care of the law that justice be done and for this reason, where the award of arbitration is sustained and enforced, it must appear that such award has been rendered by a board, or tribunal organized and conducted under the rules laid down by the courts.

To enter into an effective agreement for future arbitration of disputes that may arise, three rules must be observed:

First—The tribunal to which the disputed matter is to be referred must be definitely fixed or named in the agreement. It has been repeatedly held to be a good reference, where the parties have agreed that matters of dispute shall be referred to the architect in charge and in many cases of construction work to the chief engineer in charge. The courts have also held defective, an agreement of reference to three persons to be hereafter named. I have been unable to find

any cases in Pennsylvania arising directly upon the arbitration clause of the uniform contract, but have no doubt that this phase has been taken into consideration in drawing it.

Second—The subject matter which shall be referred, must be definitely set forth in the agreement. This of course is done in the uniform contract.

Third—The courts require that the board of arbitration shall give due notice of its meetings for hearing claims, testimony, etc., and shall conduct themselves in a proper manner and without partiality.

Where an award has been rendered by a board under these rules, it will be recognized and enforced by the courts of this State. In case of failure by either party to the arbitration agreement to pay the award, all that is necessary is to bring suit in assumpsit upon the award and judgment will be entered upon it, without allowing the question of amount to be reopened.

But the question may suggest itself: If after signing an agreement for arbitration, one of the parties refuses to submit to arbitration, what is the status of the other? The answer is this: The party willing to arbitrate may offer to do so and, upon refusal, bring suit as if no agreement had existed: or he may bring suit without a formal offer. In neither case can the other set up as a defence the arbitration agreement when he has himself failed to live up to it.

Upon the other hand when an offer is made by *A* to arbitrate under an agreement with *B*, if *B* refuses to accept said offer and elects to bring suit instead, *A* can make a valid defence upon the ground of the agreement and the courts will compel arbitration before allowing the matter to come before them.

And now having knowledge of *how* to obtain arbitration, the next question is: Wherefore should I arbitrate?

There are some cases no doubt where the amounts involved are so large and the questions so complicated that the submission to one man, or even three, involves great risk. But in the average case where dispute arises over but a small

portion of the entire contract, arbitration commends itself for several reasons.

The first and most important is its economy. I doubt if there is any one thing that figures more largely in the making of contracts than the matter of costs. In these days of sharp competition the man who does not figure his costs accurately is bound to lose money or the chance of making it. Leaving out of account the expense of a law suit (which is not the cheapest thing in the world), the crowded condition of our courts in Allegheny County and in other large centers where most of the structural steel work is done, demands that a contract be tied up for two or three years before a dispute can be adjusted in the courts.

It means that the money due the plaintiff shall be held out of his business for that time. And the settlement of the dispute by this method will, in the majority of cases, swallow up any profit that otherwise might have been earned. Upon this consideration alone, arbitration, which ordinarily results in an award and payment thereof within a short time, makes a strong appeal.

In the second place it appeals to us because of its manifest fairness in the majority of cases. We can safely say that the average board of arbitration is far superior to the average jury for the determination of the complicated questions which may arise under a building contract. The arbitrators will, in general, be men versed in construction business and in all the details, conditions and circumstances surrounding the subject matter of the contract. Granted that they are honest and impartial, they are in the best possible position to make an award in accordance with right and justice. They are not swayed by prejudice nor hampered by ignorance; and in the majority of cases their award will be more nearly correct and satisfactorily to all parties than any decision arrived at by a jury.

As a rule the structural steel manufacturer stands in the position of a sub-contractor. As regards his relation to the principal parties to the contract, the general rule of law is that he is bound to take notice of that portion of the main

contract which refers to his work or material. But the courts of this State have expressly ruled that the existence of an arbitration clause in the contract between the owner and the chief contractor cannot rob the sub-contractor of any statutory rights which he may have and particularly the right on his part to file a mechanics lien against the structure for the work and materials furnished. This right of course is based upon the further presumption that the chief contract contained no provision against liens and that the sub-contractor had complied with all the requirements of the act relating to the right of mechanics liens.

In conclusion then we can say that an effective arbitration agreement submitting matters in dispute to a duly constituted and properly conducted tribunal does not rob either party of any rights, but rather gives to both an additional remedy which will prove an economical and satisfactory method of disposing of questions at issue between them, will tend to facilitate building operations and prevent useless litigation to a large degree.

PAYMENTS

MR. L. J. AFFELDER:* It has been intimated that the line of least resistance is to use the form of contract which is at hand, whether it meets all the requirements or not. This is shown by the fact that nearly every speaker referred to the uniform contract—which should *not* be used for structural steel work. We can class with uniform contracts those contracts which for convenience are drawn up by architects for use in their own offices for any class of construction which they might undertake. These contracts are all of the same general character, regardless of the fact that they may be used for different building materials. They are intended to cover every possible contingency which might arise in any form of building operation, and it is readily seen how little they might apply to a structural steel contract.

Before taking up the topic assigned to me I want to refer particularly to the contract forms which are used in archi-

* Contracting Manager, American Bridge Company, Pittsburgh.

tects' offices drawn up for the architect's own use. I have in mind a contract which was presented to me for execution several years ago, and upon objection to some of the terms, not necessarily to the payments, the architect suggested that we go together to the representative of the owner and discuss the matter with him. We did this and it there developed that the attorney for the three parties was the same, so we adjourned to the attorney's office to settle the points at issue. The attorney had drawn up the form of contract for the architect's use, and while the contractor and the owner were temporarily out of the office he told me that he would by no means allow me to sign such a contract, that it was not intended for a reputable contractor but was intended for contractors of limited responsibility.

Now this same general statement may be made regarding the uniform contract. The uniform contract does not cover structural steel, it covers material and labor, and particularly labor in so far as payments are concerned. The usual method of making payments prescribed by the uniform contract is that monthly estimates shall be made by the architect or engineer and 85 per cent, or thereabouts, of the estimate shall be paid on a certain day in the month succeeding, and 30 days after the final completion of the contract the retained percentage shall be paid to the contractor. This might work out very well where the percentage of labor is greater than the material—which is not the case with structural steel. In structural steel, the contractor invests a very large amount of his money in raw materials and in labor preliminary to making any delivery or performing any work at the building site, whereas in contracts for other materials which can be purchased from stock as required, such as brick, sand, or cement, a large investment is not needed, in fact the larger part of the contract price is for labor and not for materials. For this reason structural steel must be considered entirely independent of other trades or other materials.

In an operation in which a structural steel contractor is interested, as a rule the owner has financed his proposition and is prepared to make payments. In dealing directly with

the structural steel contractor, that is if he is the main contractor, there should be no trouble in drawing up a satisfactory contract requiring prompt payments. If the steel contract is a sub-contract of the general contract the usual procedure is this: The general contractor draws up a form of contract which is as nearly identical to his own form as is possible under the circumstances, and the argument is that "this is the form of contract that I had to sign," regardless of the fact that it does not apply. This refers particularly to payments. It might be entirely equitable for the general contractor to receive monthly estimates of 80, or 90 per cent, as the material is erected and in place; but there is no reason why a steel contractor, whose business is entirely different from the main contract, should have to wait for his payments just for the reason that the general contractor does not get his money from the owner. In ordering his material from the mills and preparing his detailed drawings, and in fact in doing most of his work, the steel contractor practically has all his materials on a moderate sized job in his yards, has entirely completed the detailed drawings, has entirely completed the templates, has done perhaps 50 per cent of the fabrication, before he delivers a pound of material. Is it not only right that all these things should be taken into consideration in the matter of payments?

It is generally conceded in recent years that the uniform contract does not properly cover this, and there has been prepared what is called the standard contract for structural and ornamental steel and iron work, which I believe was first issued in 1907. This is a little more equitable than the uniform contract because it provides that 85 per cent of the value of the material shall be paid monthly as it is delivered and erected, that is, it specifies payments for the fabricated and erected materials. In order to make an equitable contract for moderate or large size jobs there should be additional payments. Payments should be made monthly as the material is received at the shop, additional payments should be made as the shop work is done, further payments should be made as the material is shipped, and, in an erection contract, month-

ly payments as the work is erected. This with modifications depending on the nature of the work will make an equitable contract not only for the contractor but also for the owner who has the money on hand.

There is one other point which the uniform contract does not cover correctly as far as the sub-contractor is concerned. The uniform contract usually provides that the final payment shall be made a certain number of days, usually 30, after the completion of the work. That is, if a steel contractor under such contract were to deliver and erect his material and for some reason or other it would take one, two, three or more years to complete the general contract, his payment would not be due until 30 days after the final completion and acceptance of the entire contract by the architect or engineer. That is manifestly unfair. All payments should be contingent upon the operation specified in the contract and final payment should be on this basis, just as much as the initial or intermediate payments.

Two forms of contracts used by the American Bridge Company of New York are appended, one for structural steel delivered, the other, erected, the two contracts differing only in minor details.

Attention is called not only to the terms of payment but to the other provisions, which with a few exceptions are similar to the uniform contract adopted by the American Institute of Architects and the National Association of Builders. It is these exceptions, however, that make the forms desirable for structural steel contracts as they are specifically written for this product.

Erected Work

Agreement made this .... day of .... 19.., between American Bridge Company of New York, a corporation of the State of New York, party of the first part (called the Contractor), and ...., party of the second part (called the Owner):

In consideration of the mutual promises here stated, the parties mutually agree as follows:

Article I. The Contractor will furnish and erect in place the structural steel work for the ...., located

at .... in accordance with plans and specifications ...., which are signed by both parties and made a part of this contract.

Article II. The Contractor will begin shipment of material on or before the .... day of ...., 19.., will continue shipments at short intervals thereafter, and will complete its work on or before the .... day of ...., 19.., provided all the required data is furnished within three (3) days after the signing of this agreement and the foundations for the structure are entirely completed, free from obstructions, on or before the .... day of ...., 19.., and that all lines and levels and all labor and materials to be furnished by the Owner and other contractors are furnished in such time and manner as not to delay the Contractor; and provided further, that there are no delays due to the rolling mills, transportation, strikes, fires, floods, storms, or any other circumstances beyond the Contractor's reasonable control. Should the work be delayed by any of the above causes, the Contractor will complete its work in a reasonable time under all the circumstances, among which shall be considered the condition of the Contractor's business at the time.

The Owner will complete the foundations for the structure, free from obstructions, on or before the .... day of ...., 19.., and will furnish, or cause to be furnished, in such time and manner as not to delay the Contractor, all lines and levels and all labor and materials to be furnished by the Owner and other contractors, provided there are no delays due to strikes, fires, floods, storms, or any other circumstances beyond the Owner's reasonable control. The Owner shall not be liable to the Contractor for delays due to any of these causes provided he gives the Contractor ten (10) days notice in writing of the expected duration of such delay; and the Owner agrees in any event to notify the Contractor in writing at least ten (10) days before the completion of the foundations, free from obstructions.

Article III. No alterations shall be made in the work, except upon the written order of the Owner; and the amount to be paid by the Owner, or allowed by the Contractor, because of any alterations is to be stated in the order. Should the Owner and the Contractor not agree as to this amount, the work shall go on under the order, but the amount to be paid or allowed shall be fixed by arbitration provided for in this contract.

Article IV. Upon written request, the Contractor shall provide, at such times and places as will least interfere with its operations, facilities for the inspection of the work by the Owner; but the Owner agrees that the Contractor shall not be liable for any injuries sustained by the inspectors. Any material condemned shall be

removed upon written notice and replaced by other and suitable material.

Article V. Should the Contractor at any time refuse or neglect to supply enough workmen of proper skill or materials of proper quality, or to carry on the work with promptness and diligence, the Owner, if not at fault, may give the Contractor ten (10) days written notice, and at the end of that time if the Contractor continues to neglect the work, the Owner may provide such labor or materials and deduct the cost from any money due or to become due the Contractor under this contract, or may terminate the employment of the Contractor under this agreement and take possession of the premises and of all materials, tools and appliances thereon and employ any other person to finish the work. In the latter case, the Contractor shall receive no further payment until the work shall be finished; then if the unpaid balance that would be due under this contract exceeds the cost to the owner of finishing the work, such excess shall be paid to the Contractor; but if such cost exceeds such unpaid balance, the Contractor shall pay the difference to the Owner.

Article VI. If for more than one (1) month at any time, any act or neglect of the Owner or any legal proceeding taken against him, prevents the starting or continuous prosecution of the work, the Contractor may give the Owner ten (10) days written notice, and at the end of that time if the Owner continues at fault or the legal proceeding continues effective, the Contractor may terminate its obligations under this contract; in which case the Owner shall at once pay the Contractor for the labor and materials already furnished and all damages the Contractor may sustain.

Article VII. The Contractor will indemnify and save harmless the Owner from all claims and costs arising from any damage to persons or property occurring in the performance of this contract and due to acts or neglect of employees or agents of the Contractor.

Article VIII. If at any time there shall be found evidence of any claim or lien for which the Owner might be held liable arising out of any work or materials to be furnished by the Contractor, the Owner, upon presenting such evidence to the Contractor, may retain out of any payment due or to become due an amount sufficient to indemnify him against such claim or lien, until it has been settled or discharged.

Article IX. The Owner will pay the Contractor the sum of .... in funds current at par in New York City, as follows:

On or about the last of each calendar month, an approximate estimate shall be made by the Contractor of the value of material received and work performed up to that time. In these estimates raw material delivered at the plant shall be valued at fifty per cent.

(50%) of the price of the comp'eted work; fabricated material ready for shipment, at seventy-five per cent. (75%) of such price; material completed and shipped, at eighty per cent. (80%) of such price, and erected material, at one hundred per cent. (100%) of such price. Ninety per cent. (90%) of such estimates shall be due and payable within ten (10) days after they have been made up. The retained ten per cent. (10%) shall be paid upon the final completion of the work. Should this contract cover more than one separate structure, payment in full for each structure is to be made upon the completion of that structure. The retained percentage shall in no case exceed double the value of the work to be done.

Th Contractor shall, upon request of the Owner, furnish a bond for the faithful performance of this contract in an amount not exceeding twenty-five per cent. (25%) of the total contract price. This bond shall be in lieu of the retained percentage, and if it be furnished, all monthly estimates shall be made and paid to the full value of the work performed and materials furnished.

Failure by the Owner to make payments at the times provided in this contract shall give the Contractor the right to suspend work until payment is made, or at his option, after thirty (30) days' notice in writing, should the Owner continue in default, to terminate this contract and recover the price of all work done and materials provided and all damages sustained; and such failure to make payments at the times provided shall be a bar to any claim by the Owner against the Contractor for delay in completion of the work.

Article X. The work shall be inspected for acceptance by the Owner immediately upon receipt of notice that the work is ready for inspection and the final payment shall be conclusive evidence of the performance of this contract.

Article XI. Any difference or dispute arising between the Owner and the Contractor shall be referred to three (3) disinterested arbitrators, one to be appointed by each of the parties to this contract and the third by the two thus chosen; the decision of any two shall be final and binding and each of the parties shall pay one-half of the expense of such reference. In case of the death or inability to serve of any of the arbitrators, a new board shall be chosen if the parties so desire.

Article XII. The Owner shall maintain during the progress of the work full insurance on the work, in his own name and in the name of the Contractor, against loss or damage by fire. The policies shall cover all work incorporated in the building, and all materials for the same in or about the premises, and shall be made payable to the parties as their interests may appear.

IN WITNESS WHEREOF, the parties have duly executed this agreement as of the date first given.

Attest:

American Bridge Company of New York,

By ....

.... [Seal]

.... [Seal]

Delivered Work

For delivered work Articles I, II, V, VII and IX are changed as follows:

Article I. The Contractor will furnish the structural steel work for the .... located at

....

delivered f. o. b. cars ...., in accordance with plans and specifications.................................. ...., which are signed by both parties and made a part of this contract.

Article II. The Contractor will begin shipment of material on or before the .... day of ...., 19.., will continue shipments at short intervals thereafter, and will complete its work on or before the .... day of ...., 19.., provided all the required data is furnished within three (3) days after the signing of this agreement, and provided, further, there are no delays due to the rolling mills, transportation, strikes, fires, floods, storms, or any other circumstances beyond the Contractor's reasonable control. Should the work be delayed by any of the above causes, the Contractor will complete its work in a reasonable time under the circumstances, among which shall be considered the condition of the Contractor's business at the time of resuming work.

Article V. Should the Contractor at any time refuse or neglect to carry on the work with promptness and diligence, the Owner, if not at fault, may give the Contractor ten (10) days written notice, and at the end of that time if the Contractor continues to neglect the work, the Owner may provide such labor or materials and deduct the cost from any money due or to become due the Contractor under this contract, or may terminate the employment of the Contractor under this agreement and employ any other person to finish the work. In the latter case, the Contractor shall receive no further payment until the work shall be finished; then if the unpaid balance that would be due under this contract exceeds the costs to the Owner of finishing the work, such excess shall be paid to the Contractor; but if such costs exceeds such unpaid balance, the Contractor shall pay the difference to the Owner.

Article VII. The Owner shall make no claim for compensation on account of shop errors or misfits, unless the Contractor has had due notice and an opportunity to inspect and pass upon such errors or misfits.

Article IX. The Owner will pay the Contractor the sum of .... ($...............), in funds current at par in New York City, as follows:

On or about the last of each calendar month, an approximate estimate shall be made by the Contractor of the value of material received and work performed up to that time. In these estimates raw material delivered at the plant shall be valued at fifty per cent. (50%) of the price of the completed work; fabricated material ready for shipment, at ninety per cent. (90%) of such price, and material completed and shipped, at one hundred per cent. (100%) of such price. Ninety per cent. (90%) of such estimates shall be due and payable within ten (10) days after they have been made up. The retained ten per cent. (10%) shall be paid upon the final completion of the work. Should this contract cover more than one separate structure, payment in full for each structure is to be made upon the completion of that structure. The retained percentage shall in no case exceed double the value of the work to be done.

The Contractor shall, upon request of the Owner, furnish a bond for the faithful performance of this contract in an amount not exceeding twenty-five per cent. (25%) of the total contract price. This bond shall be in lieu of the retained percentage, and if it be furnished, all monthly estimates shall be made and paid to the full value of the work performed and materials furnished.

Failure by the Owner to make payments at the times provided in this contract shall give the Contractor the right to suspend work until payment is made, or at his option, after thirty (30) days notice in writing, should the Owner continue in default, to terminate this contract and recover the price of all work done and materials provided and all damages sustained; and such failure to make payments at the times provided shall be a bar to any claim by the Owner against the Contractor for delay in completion of the work.

RELATIONS OF THE ARCHITECT TO OTHER PARTIES IN A CONTRACT

Mr. O. M. Topp:* The ideal contract, from an architect's point of view only, is one which will be the means of producing the best results with a minimum of care and attention on his part.

There have been different methods employed in letting contracts, but the one most in use is that embodying the en-

* Architect, Empire Building, Pittsburgh.

tire work in one contract, the purpose being that the architect will have only one firm to deal with, which will be made responsible to him for the carrying out of all work done by the different trades on the building.

As the general contractor usually is a master of one trade only, he enters into sub-contracts with the other trades in the building.

There are various objections, however, to this kind of a contract for we must consider that the sub-contractors, in a sense, are parties to the general contract and then we find that a general contract system is not equally just to all parties. The sub-contractor is frequently at the mercy of the general contractor, both at the time when he is entering into the contract in the matter of price, and afterwards held responsible for delays which may not be directly caused by him, also for damages beyond his control.

The sub-contractor will probably not receive his payment as promptly as if he had a contract direct with the owner.

The disadvantage to the architect in this form of contract is mainly this: If the general contractor does not have a proper organization, he is, himself, unable to pass on the work of the different sub-contractors and the result is that any work will pass that is not objected to by the architect, and if objected to by him, he will turn his sub-contractor over to the architect for adjusting any difficulties that may arise, also for any explanation and data required in his work. If these requests are complied with, the object of the general contract is partially defeated, that is, having to deal with one party only.

Another objection to the general contract system is the difficulty of getting good and reliable sub-contractors.

In these times of sharp competition, the lowest bidder is usually awarded the work, and to be low bidder, he must use low sub-bids, which frequently means poor sub-bids. To partially overcome this difficulty, contractors are requested to submit lists of their sub-contractors and the architect will have the privilege of choosing better sub-bidders at an in-

creased cost, provided he is able to impress upon the owner the advisability of making such substitution.

This is, however, a very difficult matter to do. The owner usually has only the following points in view: The minimum cost of the building, the specifications, the contract and the architect to enforce the contract. With these things at hand, the owner may expect Greek ornaments to be executed by a negro hod-carrier.

In view of these difficulties, we naturally turn to other possible methods for drawing up contracts. The nearest at hand is to make a contract for each individual trade in the building, but as this would require not less than 14 contracts, it will readily be seen that the ordinary equipment of the architect's office would be entirely inadequate and the work too expensive to handle in this way, without material increase in the usual compensation.

There are, however, different trades that may be separated from the general contract more easily and to better advantage than others. Among these are Heating, Plumbing and Structural Steel Work and separating these trades from the general contract is becoming quite customary.

There is still another method of placing contracts which seems to be gaining in favor, and that is, to place the work in the hands of a construction company at a fixed fee. This fee to include a profit as well as the expenses of handling the work. After this agreement is made, the construction company is ordered by the architect to receive bids for the different parts of the work. These bids are then opened and tabulated in the presence of the owner and the architect, who will then make the award. This manner has the advantage of being able to place the work in better hands and gives the architect the opportunity of handling the work largely through one party and without a specially arranged office organization.

RELATIONS OF THE ENGINEER TO OTHER PARTIES IN A CONTRACT

Mr. V. R. Covell:* The engineer sustains a very important relation to the contract. He may represent either

* Deputy County Engineer, Pittsburgh.

the owner or the contractor. If the former, it is his duty to obtain the very best possible construction for a fixed sum or to secure definite quality and quantity of work for the least possible expenditure. If he is employed by the contractor these conditions are reversed.

When employed by the owner it is his duty to prepare and interpret the plans and specifications, and it is in this connection that his skill and knowledge should be used to the very best advantage. Every point of the specifications and every detail of the plans should be carefully studied in every possible aspect. Even then experience shows that difficulties and unforeseen conditions will arise. For the best results in getting cheapness and quality he must keep constantly in touch with shop practice and with the quality and kind of materials best adapted to the work.

The good engineer in charge of work for either the owner or the contractor will keep systematic and careful notes. While many engineers do this, others trust to memory or incomplete notes. The right kind of notes are useful in making up estimates and invaluable when disputes of any sort arise between the parties interested.

In addition to the requirements for knowledge of engineering details and materials, the engineer, like the architect, must have judicial qualities, and above all he should possess integrity. One of the vexed questions which the engineer and architect must meet is that of extras. If his employment is on a percentage basis, his position is peculiarly difficult. If he allows an extra at a good round figure, it increases his compensation, or if he refuses to allow an extra or allows it at a reduced price his compensation suffers in proportion. The less competent and careful the engineer, the greater the possibility for extras.

Recently there have been so many exposures of breach of trust that one is prone to scrutinize every transaction for signs of graft. The engineer is fully as liable to be tempted to sacrifice honor for gold as are those in other walks of life, and opportunities to take advantage of either the owner or the contractor are frequently present. Whatever his skill or

knowledge, without integrity the engineer should not be placed in a position of responsibility on important work.

RELATIONS OF THE INSPECTOR TO OTHER PARTIES IN A CONTRACT

MR. EDWARD GODFREY:* In the term inspector I will include not only the mill and shop inspectors, whose duty it is to look over the materials and workmanship; but also the engineer who examines the shop drawings to see that the specifications have been carried out in their preparation. This work is generally classed as consulting engineering, but much of it is done on a tonnage basis the same as inspection.

The primary idea of an inspector is probably best expressed in the law term *caveat emptor*—let the buyer beware. He is eyes for the buyer. A purchaser of a bridge, an office building, or any other thing that requires expert knowledge to pass upon, if he is wise, will employ an expert to see that he is getting what he pays for. This phase of an inspector's office is well understood. To some minds, however, the inspector is merely a critic, a fault-finder. In the nature of things he must be a fault-finder. Perfection is only reached by eliminating faults. If an inspector looked for good points only, or largely, his opinion or report would be misleading or dangerous. One fault may be serious enough to cause a wreck. Manufacturers are sometimes provoked at an inspector because of the fact that he emphasizes faults and appears to overlook the good points in a piece of construction. The lateral system of a bridge may be faultless up to the connection with the shoe, but if this is a bent plate which would straighten out under a small stress, the perfection of the remainder of the lateral system counts for very little. Of course perfection cannot be attained, but imperfections may appear small and yet be great enough to be serious faults.

Generally, an inspector is employed and paid by the buyer, and this gives the buyer the right to look for services devoted to himself alone. Some contracts provide that the seller must pay for inspection, but of course this is added to the price the buyer must pay and the relation to the buyer

* Engineer with Robert W. Hunt Co., Pittsburgh.

is unchanged. As an employee of the buyer the inspector's chief duty is to see that the specifications are carried out.

An inspector in common justice must look on matters from the seller's view point, and furthermore there are many reasons why a manufacturer should regard him as an aid to his business rather than a hindrance. An inspector can do much to aid the manufacturer and in doing so further the interests of his employer, the buyer, and the wise manufacturer will appreciate this. It raises the standard of work to have constant critical supervision exercised over it. It seldom costs more to do a thing right than to do it wrong, and an inspector whose presence is an incentive to the workmen to do the thing right, rather than to have to do it twice, is increasing the efficiency of the shop. So that even considering the character of the workmanship, a good inspector, properly treated, pays for the trouble he may sometimes make.

Buyers sometimes have the idea that the employment of an inspector is sufficient assurance of receiving the best kind of work that can be made. They overlook the fact that a shop with certain equipment and a certain class of skilled laborers can only reach a degree of perfection commensurate with the plant and the skill.

Though some shops look upon the inspector with disfavor, there is a class where he is looked upon as a convenience to find errors. This of course is not objectionable when it does not foster carelessness on the part of the shops. The writer knows of a case where a bridge company recommended to the purchaser that the detail drawings be checked, of course at the purchaser's expense; and then served notice on the inspecting firm doing the checking, that they would be held liable for any errors in fitting in the field. They thought in this manner to save themselves the expense of checking their own work in the drafting room. This brings up a very important phase of the inspector's relation to the parties of a contract, namely, his liability or lack of it.

If an error is found after an inspector has passed upon work, is he liable for the expense of correcting it? Some contracts specifically state that the acceptance of work by an

inspector does not forfeit the right of the purchaser to reject it or have it made satisfactory, if subsequently found defective. But of course a contract might say this, and a court might rule that it is unreasonable and invalid. It is not possible for an inspector to discover every error or fault. He may sound a casting and use every means in his power to discover any imperfection, but when it is put in the lathe, large cavities may be found that necessitates its rejection. Should the inspector be made to pay for the new casting, when the commercial means for inspecting the casting would not have discovered its fault? A beam was found by the field inspector to be cracked beside a flange hole after it was in place in the building. Shop inspection cannot, in the present state of things, be extended to tapping beside each rivet hole or examining it microscopically to detect cracks. The manufacturer's workmen can tell when such cracks occur, and should be instructed to report them. If an inspector finds an error in the shop, it is corrected by the manufacturer without question. Why then should he not correct it in the same manner in the field? It is true that it may cost him more in the field than in the shop; but he is correcting his own error, and he would be obliged to do it if there were no inspector on the work.

There is a class of inspection where the inspector is in fact and solely an employee of the seller. This is what might be called auto-inspection. It is the manufacturer inspecting his own goods. Such inspection is usually very rigid on foreign shipments. It is sometimes rigid on a job where the purchaser has half a dozen engineers on the job in the field. It is not to be expected that an inspector will cause his employer what he believes to be unnecessary expense. It is only natural that his judgment will be colored by considerations of his employer's interests.

DISCUSSION

Mr. C. B. Albree:* The class of contractors I have had to deal with has been engineering companies rather than architects; with corporations manufacturing bridges, etc. Those

* President, Chester B. Albree Iron Works, Pittsburgh.

contracts have usually been in the nature of an exchange of letters; a proposition made in writing to do certain work according to plans and specifications furnished by the other party, or that we furnish. It has always been our endeavor to make these as clear and concise as possible. The order itself is generally a letter accepting the proposition. We have done probably 90 per cent of our business in this way, and with honest men I know of nothing better. In very large contracts covering a great variety of details it may be necessary to have more than this, but I do not see the necessity if the plans and specifications are clear. The difficulties that have arisen in the past, in our experience, have generally been due to a failure to understand clearly what the work is, either in the specifications or plans.

I think it is more a matter of failure to reach such an understanding before doing the work than in making an iron clad contract which, from all I can learn, it is difficult to have the courts make any party to live up to its requirements.

Mr. V. R. Covell: I would like to inquire whether, under a contract such as Mr. Affelder proposes, there would be any appreciable difference in the contractor's price at which such materials could be furnished.

Mr. L. J. Affelder: Matters of this kind are usually fixed by competition, and in all phases of the contract the responsible contractor must meet the irresponsible contractor, and I think that would apply to the terms of payment as well as to anything else.

Mr. J. A. McEwen: In regard to the uniform contract, in casting about for something to anchor to, something on which to base our contracts, it was selected for that purpose. I agree with Mr. Affelder that it is not just the proper thing for structural steel without a good many modifications.

Mr. Emil Gerber:* I have not much to say except that in the past, the opinion prevailed that every contractor was a thief. In recent years a great many engineers have gone into

* Assistant to the President, American Bridge Co., Pittsburgh.

the contracting business, and, this being so, the old opinion cannot possibly apply now, as everybody knows that engineers are honest. If, however, a purchaser still entertains that belief, honest contractors should avoid him if practical. A manufacturer or contractor cannot stay in business for any length of time unless he makes an honest effort to comply with the specifications. If the architect, engineer or inspector is disposed to be fair and reasonable in the interpretation of the specifications and exercises the judicial function mentioned rather than the belief that he is on the work to get the very last possible advantage for the owner, the contractor, as a rule, has little to complain of. To insure such fair-minded, judicial stand on the part of the architect, engineer or inspector, it is necessary that he shall have experience and a thorough knowledge of the work on hand, and I am sure all present who had had experience in the structural line will bear me out in saying that if the inspection is done by experienced people in a reasonable manner with the intention of doing the right thing as between contractor and purchaser, the manufacturer or contractor who stays in business is disposed to do the work properly.

MR. S. E. DUFF:* I would like to emphasize the remarks of Mr. Gerber. I think they cover this matter in a short space very well. I wish to bring out the fact that the real essentials of a contract are honesty of intention and knowledge of the work covered by the agreement on the part of both parties. If this principle is conscientiously adhered to, a great deal of the discussion here tonight in regard to different forms of contracts, the so-called uniform contract, contracts in favor of the owner, or contracts in favor of the contractor is beside the subject. The courts are compelled to go back to the question of the honesty of intention and integrity as well as the knowledge of the parties to a contract in litigation, in order to determine whether or not there has been mutual understanding and agreement. Without mutual understanding and agreement there can be no valid contract, and this should be

* Consulting Engineer, Empire Building, Pittsburgh.

kept in mind by all who attempt to prescribe forms or regulations for making contracts.

MR. R. W. KNIGHT:* There seems to be a disposition on the part of many general contractors to insist upon contracts which are manifestly unfair to the sub-contractor. I have in mind one that was presented to me today. One of the principal points to which I took exception was that it was a *no-lien* contract. We were asked to sign away our right to lien the building in question. Now while the owners of the building were undoubtedly responsible, and the general contractor probably so, no sub-contractor or general contractor should be asked to sign away all right to lien when that is the only recourse he has. Another clause in that contract provided that in the event of the failure of the sub-contractor, in this case the structural steel contractor, to fulfill in every respect the provisions of his agreement, the architect was to be the sole arbiter of any damages which might be fixed in case the general contractor were required to pay such damages and that the sub-contractor would be required to pay his share; the architect having the right to decide as to how much this share should be. Of course exception was taken to this clause as well. Then there was that indefinite clause to the effect that "Time is the essence of the contract." This has caused a great deal of trouble to many of us and I think it should be eliminated in favor of a definite penalty and bonus arrangement which, though it might not be good in law, gives an opportunity for settlement without such expense.

Then as to the matter of surety bonds. Many architects require general contractor and sometimes each sub-contractor to file a bond. This also leaves an element of uncertainty which should be eliminated and, if necessary, a definite penalty and bonus clause substituted. I think, as Mr. Duff has said, most people will not give a contract to a company unless they are confident that the company intends to fulfill it to the best of its ability, and all the bonds, or penalty and bonus clauses that can be put into a contract do not affect the situation very

* Contracting Engineer, McClintic Marshall Construction Co., Pittsburgh.

much, where fair dealing is intended by both parties to the agreement.

Mr. O. M. Topp: The furnishing of bond is always objected to by contractors.

If the contractor proposes to fulfill his agreement, there should be no such objection. A bond enables the architect to issue certificates for larger payments on contracts. Both the contractor and the owner should furnish bond.

The larger payments required by steel contractors can be arranged when such contracts are made directly with the owner. In large buildings where the steel forms one of the largest items of cost, a special contract could easily be arranged for.

Mr. Willis Whited:* It has been said that many contractors are dishonest, and a number of them are, of course. My experience has been mostly with public contracts where the law requires that it be given to the lowest responsible bidder, and unless the contract is so worded that the incompetent or dishonest contractor has no chance to ply his nefarious trade, it is the dishonest contractor who usually gets the job, and the specifications have to be drawn to cover such conditions, and this is more apt to be the case where there are sub-contractors. The general contractor usually lets the component parts of the work to the lowest bidder that he can possibly persuade the owner to accept. Sometimes they know something about their work and sometimes they do not; sometimes they are honest and sometimes they are not. I have had a little bitter experience in this line myself.

Mr. J. A. McEwen: I would like to ask Mr. Adair whether a contract carrying a clause which is contrary to common law, will stand the test when it reaches the courts, such as a clause to take possession of a contractor's tools on the job in case he fails to complete the work on time?

Mr. W. B. Adair: Do you mean where the owner attempts to seize the tools of the contractor on the ground and use them? Of course the owner could not do that unless the

* Assistant Engineer, Bureau of Construction, Pittsburgh.

contract gave him the right to do so. If the contract gave him the right to do it, he could exercise that right. The right might however be rather difficult to enforce, as the contractor might take away the tools.

Mr. J. A. McEwen: If he signs away his right and gives the owner that privilege, he is bound to do it. I knew of a case where this was done and the contractor sued the owner and obtained judgment. I do not know what the nature of the contract was.

Mr. W. B. Adair: It would depend a great deal on that and on whether the contractor was really in default If the owner simply said he was in default and the jury took a different view of it naturally the contractor would win. After all in so many of these cases it does not depend so much on the facts as on what the jury is convinced of.

RAPID TRANSIT FOR PITTSBURGH

A DISCUSSION

PRESIDENT BARNSLEY: Our meeting in the Chamber of Commerce is unusual, but the subject tonight being of great interest to Pittsburgh, it seemed necessary to have larger quarters, and I take this opportunity of expressing our appreciation of the courtesy extended to us by the Chamber of Commerce.

We hear a great deal about the makers of Pittsburgh. To my mind a large percentage of the makers of Pittsburgh are in some way connected with the engineering profession. The large number of our membership and the prominent names on its roster prompts me to say that they have been very modest in the past and the laymen have probably not thought of them in the way they should.

When we started our year's work in 1909 it seemed that, considering the greatness of Pittsburgh and the many problems arising through its peculiarities of location and public necessities requiring technical skill in their solution, men of technical training should give some heed to those needs rather than confining their discussions at our meetings to strictly technical subjects. There are two things in this connection that to my mind Pittsburgh needs. First, there should be a survey of Greater Pittsburgh in order that all the various matters of elevation and topographical features could be accurately known and marked by monuments with a line of triangulation as a starting point. The other important matter is the topic we have for discussion tonight, Rapid Transit for Pittsburgh. And the discussion should be from a neutral stand point and based on the broadest lines. When rapid transit is mentioned some people immediately think of a subway to the East End ; others of a tunnel through the south

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hills; and still others of an elevated structure. They form a concrete idea of some one thing that should be done. Rapid transit in Pittsburgh will be a combination of many things, and this is the spirit in which I hope the discussion will be carried on tonight. And in order that the development may be carried on rapidly and give us the needs of the immediate future, let us do something to this end.

Now who should be the first to give this opening word? To my mind the man who opens this discussion is the man best beloved in all Pittsburgh, a man who has Pittsburgh at heart, a man who has used and is using his best scientific skill to give Pittsburgh the best information within his power, Dr. John A. Brashear.

Dr. J. A. Brashear: Mr. President, gentlemen of the Engineers' Society and invited guests, I am proud to do anything I can that will be for the good of this dear old Smoky City. New Yorkers may say that Pittsburgh has but 28 righteous men, Philadelphians may say of it, Washingtonians may say it, but I think we are all willing to stand our chances of finding more than 28 righteous men in old Pittsburgh.

I can remember many years ago when the Society met in a little room on Smithfield Street. There were not many of us. Our good friend Metcalf was there always, and at one of the meetings I stood up before that august body and read my first scientific paper, with my knees shaking together; but it gave me encouragement when President Metcalf came up and said, "I want that paper published." I may say without egotism that more than 500 copies of that were sent out by request, because I was telling secrets outside of the shop, some things that were out of the ordinary at that time. The older members can remember that charming paper read by Mr. Metcalf on what it means when we harden steel. I am proud to have a copy in my archives yet.

I want to say that I think we have been altogether too modest in this Engineers' Society. Its influence has been felt from that day to this, and will be felt not only in scientific matters, but in civic righteousness and even in com-

mercialism, if you please. I remember some years ago, a committee was appointed by this Society to have a talk with the then head of the Department of Public Works, a man who did great good for the City of Pittsburgh, but who thought the Engineers' Society had no business to interfere, as he expressed it, with his prerogatives. We went to the City Hall and sat outside his door on chairs like "bound boys at a husking" waiting our turn. We had been appointed to help abate the smoke nuisance, not to stop it, but to do the best we could to help the situation. And the response we got! After a long period of waiting we were ushered into the august presence, and after a few moments he said: "Gentlemen, it is no use for you to come to me. I am going to sue every concern that is making smoke, and that is the end of it." But a better day has come, and they must listen to engineers who have not only a real interest in their calling, but the interests of the city at heart. We are growing better and better, and the time will come when old Pittsburgh, with all her smoke, will stand out as a model city.

Some of you can remember the inception of the Academy of Science and Art in our rooms down on Fifth Street. We had a baker's dozen at the first meeting; you have seen it in recent years crowded to its limit. And you have seen develop out of it the Museum, the University, the Technical School. I was proud when a citizen of Pittsburgh a short time ago sent for me and gave me a quarter of a million dollars to be used for the betterment of the public schools of our city. We are doing better and better all along the line.

Now what has all this to do with the question of rapid transit? It means that we have been moving along during the past 25 years. I remember when Quincy, one of the grandest members we had in the old Society, told us about the history of the Baltimore and Ohio Railroad. He was one of its first engineers when they ran their trains through the day and when night came they stopped until the next morning. And you remember how he got that bridge across the Potomac during the early days of the civil war. Gentlemen,

it is a wonderful age we are living in. I read the other day of a fellow who was trying to dodge an automobile, when a flying machine struck him and he fell down an open coal hole and was hit by an underground railroad train. I do not know whether flying machines will ever be a commercial venture, but for three years I was associated with that splendid man, Langley, who was almost cursed by some men for fooling away his time at the old Allegheny Observatory. He was carefully experimenting to find the law of flight and how much energy he would have to put into a flying machine to hold up a certain weight against the resistance of the atmosphere at certain speed. Those Wright fellows, though they take most of the credit to themselves, are in great measure, so far as the scientific side is concerned, dependent on the wonderful researches of Professor Langley up on the old hill. I am pleased to say that the Smithsonian Institution has asked me to serve as a member of a committee to award a gold medal every year to the man who has done the best work in aerodromics, which is to be called the Langley medal.

I do not know how we are going to solve the question of rapid transit. I wish I did. I could solve the question better how to get to that far off star whose light takes a hundred years to reach us. We have made some progress in that direction, but we are making advancement in every line of study. The man who says the end has been reached is a very foolish man. Methods of transit have shared in a large degree in this advancement, and there are gentlemen here who have made this subject of rapid transit in our own good City of Pittsburgh a hobby, who can and no doubt will enlighten us this evening in a way that will be of value to us all, and I trust may be helpful in solving the problem in which every citizen is interested.

President Barnsley: I am sure we are gratified at having Dr. Brashear speak to us tonight. And as I happen to know that he will have to leave early I want to say for his benefit that city officials today are not just what they were when he had his experience.

Mr. L. C. Moore: It is presumed that all interested have read about and discussed more or less some method of improving the local traffic conditions in regard to the saving of time in transit, but more particularly with regard to relieving congestion during the so-called rush hours of our local street car service. As a city we are not an isolated case by any means, conditions being similar in a large majority of our cities, presumably because of lack of experience as to the proper methods of dealing with the problem. It is noted that cities abroad have solved the question of congestion of local traffic, in most cases, by compelling the public utilities corporations to display a sign "No seats" when the conveyance is full. It has been possible for them to do this because their conditions are far different, and they are not in so much of a hurry.

A great deal of time has been and is being spent, and even private funds contributed by public spirited citizens, for bettering our conditions. The Chamber of Commerce, Boards of Trade, a Civic Commission, and individuals have offered suggestions, and committees have passed resolutions, agitated the question through the press, submitted propositions to those in authority connected with the Railways Company, and even the highest tribunal of the city, the Mayor, and his heads of departments, do not escape the clamor for better conditions, so far without very much having been accomplished. All of this would seem to lead toward what may be a fact, that under present conditions no one has the necessary authority, or if they have, are not in a position to exercise it in a way that will benefit the public.

There is no desire on the part of the writer to pose as an expert on the subject before us, but rather as a citizen, with no other object in view than that of the agitation of the question.

The indications of today are that the steam railroad companies entering the city are not favorably disposed toward furnishing, strictly speaking, rapid transit for what may be termed short haul passengers, say a maximum distance of six miles, for the same rate of fare that the street railway

companies are compelled to accept. Assuming this to be a fact, our trust is placed with the street car companies, and if experience proves they cannot keep pace with the growth of the city, it then becomes necessary for the consideration of some means of improvement.

It is possible there would not be so much complaint regarding the surface car system if all the patrons were sure of a seat every time it is necessary to make a trip, and the question arises, do all of us always want seats? Studying this feature a little indicates that some would rather stand than wait for another car or two. There is another cause which adds appreciably to the congestion during the early evening rush hours. That is the tendency of lady shoppers to take chances of getting seats by prolonging their store calls. Another probable cause of the popularity of the strap in this city is the fact that the long haul cars are compelled to provide for a comparatively large percentage of short haul passengers, and there is no better method known for improving these conditions than that of agitating the question, with an avowed determination of ultimate successful results.

Without doubt there are enough surface cars in Pittsburgh and the outlying districts at all times, except during the rush hours, and a great deal of time and energy has been and is now being expended in the form of advice, suggestions and criticisms, requesting or attempting to coerce street car officials to provide their patrons with more seats and a more liberal use of transfers. As to whether the management can accomplish this without loss, it is impossible to say, but the present policy of management has been going on in this and other cities for a long time, and will continue to give both them and ourselves cause for complaint for years to come, or indefinitely, unless we take advantage of strenuous means with a view of remedying the trouble. It must be admitted, however, that generally speaking the service in this city has been and is now being improved on some streets, and improvements would materialize with greater rapidity if it were apparent to the officials that it would pay them and their stockholders.

Without doubt the owners of the street surface franchises are doing all they can, consistently, towards better results. They install more and better cars, and take such other steps toward improvements, whenever and on whatever lines seem to them advisable, and they have their problems of daily and even hourly occurrence; but their policies do not always assist as much as the public would like toward better transportation facilities.

The City of Pittsburgh, after having secured the necessary legislation, could construct a double track elevated road, commencing at a point on Liberty Ave., say one or two blocks east of the B. & O. R. R. crossing on this street, and running thence through Liberty Ave., eliminating two bad railroad grade crossings on the way down town, then looping around a block and back again. Such a structure might be leased to the Pittsburgh Railways Company, who could run cars over this double track at practically express speed without any stops and thus save time; but very likely a plan of this kind would not appear to the Railways Company as worthy of consideration, for if so, they would have asked for a franchise long ago. Also, the question of possible damage might prove prohibitory, and under present conditions they get the fare just the same. But if this were practical and the road were constructed, with a saving of say ten minutes to 50 percent of the residents east of this point, it is obvious the route would prove popular for residents who could avail themselves of this service, and to such an extent that the authorites might not think it necessary to take up the question of "Rapid Transit" at present.

Nothing has been said thus far but that which all are presumed to know. Therefore this leads to the question, are we satisfied with existing conditions, or is it time to commence the consideration of a remedy, by first securing the necessary authority, after which the question is: How shall it be accomplished in a satisfactory manner, not only to ourselves, but to our successors? The latter more particularly, because in all probability they must pay for any improvements leading to rapid transit in the true sense of the term. There is no

other question to consider if this be omitted, because as a city, our transportation facilities by means of surface cars are equal to any and superior to some; eight miles an hour might be satisfactory if we all had time for transit, and if we had seats. What more could we ask for, except, perhaps, some of our time saved? And again, if we desire to gain this feature for ourselves possibly, and surely for our successors, we must go about the consideration of the question, after having obtained the necessary authority, in the most intelligent manner, and in a way which we are confident will ultimately produce results.

If we are ready to discuss rapid transit primarily for this greater city, it is correct for laymen to assume that there are no insurmountable engineering or financial problems in the way. If later it is learned that some exist, or which for the moment may appear as such, we have the men at hand who can take care of them without the aid of experts from other cities. Rapid transit cannot be accomplished successfully, at the same time relieving congestion during the rush hours, except with four parallel tracks, in whatever directions the greater density of population demands, the two center ones for express service with an average speed, including stops, of 45 miles per hour, and with not more than four stops between terminals for, say, a seven mile haul. The two outside tracks to be used as feeders for express service and also for local traffic. It is not necessary for the latter to be located at all points under the same streets as the express tracks. They must, however, converge at express stations.

Rapid transit cannot be accomplished except under our streets and hills; possibly by elevated tracks to and over our rivers, thence through the hills by means of tunnels for the North Side and South Side. It is necessary that both of these sections be amply provided for because the territory lying in these directions is the most available for the future growth of the city.

It is not the intention at this time to locate a down town terminal, but I would advance the opinion that the east side of Smithfield St. is the most available point, about 15 ft.

above, or below, the present curb line. A terminal west of this street is not practical, due to the comparative cost, as the only point to be gained would be the saving of a short walk for the patrons, which would not prove objectionable if it were possible for them to get home in ten or fifteen minutes. It is less expensive to purchase a private right of way for a loop such as would be required than to go below the present street grades west of Smithfield St.

Referring again to this down-town terminal, let us assume it is necessary to purchase all of the ground, with buildings, demolishing the latter, bounded by Smithfield St., Oliver Ave., Cherry Alley and Fifth Ave., including the ground necessary for a right of way until the four tracks disappear beneath the street grade under the first hill. If this were possible, this small block would prove attractive, not only for terminal facilities, but as a possible site for municipal buildings similar to the Hudson Terminal Buildings in New York City. They would be amply large to meet all requirements for the next 50 years, and no one will raise a question as to the location or its adaptability for both purposes. The question of expense is not for us to consider, as we know from statistics that the wealth of the city as compared with that of others is sufficient. Therefore, no reason appears that would seem to make it necessary for us to hesitate about the consideration of the expense of so comparatively small a matter as "rapid transit" for future generations, at least.

If a terminal loop is located at some point as above referred to, the first serious problem is getting away from it towards the densely populated distrcts. Toward the North Side or South Side, either elevated structures or tunnels would be available. If a tunnel be considered toward the East End, the Pan Handle Railroad might be, due to the grade, a serious obstacle. But these are problems. It will be admitted, however, that if we can pass this railroad by tunnel either above or below, the remainder of the way towards and through the East End appears attractive for the purpose. A straight line might be followed to the junction of Center Ave. and Craig St.; thence under the former to and under Penn Ave.; under

Frankstown Ave. to Kelly St. and on to the terminal. The excavated earth could be used to advantage in filling the objectionable and so far useless ravines along the route, thus making more property available for expansion, as well as for grading certain down-town streets, raising them above high water mark.

In connection with these ideas, it appears necessary to undertake the elimination of the possibility of one or two erroneous opinions. Rapid transit for this city cannot be accomplished if other, or surface, cars are permitted to use the same tracks. Surface cars are only of use as feeders by means of transfers. The rapid transit system must be entirely independent. This is proven by practice in other cities. In Greater New York rapid transit is an accomplished fact, and without, so far as is known, any serious interference with the earnings of the surface cars. Boston, thus far, has not proven it as accomplished. It is true, their facilities are comparatively far superior to ours, and in this connection we, as citizens of Greater Pittsburgh, cannot admit that the growth of Boston is such as to demand rapid transit any more than Pittsburgh. Comparing the tonnage and value of manufactured products of the two cities, indicates the employment of labor in Pittsburgh which requires even more extensive transportation facilities than Boston. Pittsburgh is in a class by itself in this respect; but the fact remains that Boston's local city traffic conditions are far superior to ours.

Now as to financing a system such as is outlined, it must be done by the city itself, and the most skeptical will admit that the possible revenue, plus the additional taxes derived from increased valuations of real estate, if properly managed, would provide not only interest on bonds, but a sinking fund sufficient to take care of them at maturity. And further, it is time lost to consider the remote possibility of interesting private capital in furnishing this city with rapid transit.

The above preliminary outline appears like a plan of considerable magnitude; but it is the only practical remedy for congestion of local city traffic that presents itself under the existing conditions, because it will be admitted that our present

franchise owners cannot be persuaded into furnishing something they do not have on hand, or cannot purchase without involving too much capital, especially when it does not appear to them as a paying investment. Therefore, in taking this matter up, if it is learned we do not have the necessary ordinances or laws to permit us to commence operations, the proper steps should first be taken with this object in view. As to the most practical way of handling this question, the experience of other cities has been that the most intelligent method is with a Rapid Transit or Civic Commission, call them what you like, *but they must be given power to investigate and act,* as relates to all preliminary research. Then we will have commenced at the beginning. We cannot get rapid transit, in the true sense of the term, in any other manner, and it will take time. Neither this generation, nor even the next, will be expected to pay for it, but what will future generations say respecting our lack of forethought if we do not make provision for them. It may be considered that we should let them look after themselves; that it is too soon for us to commence; but the indications of today are that it is not too soon. If we wait too long, it will be too late for us, or even them, to accomplish anything in this line.

Mr. H. W. Fisher: In order to get some idea of the success of rapid transit, I wrote a letter to Mr. H. G. Stott, Superintendent of Motive Power of the Interborough Rapid Transit Company, and he sent me the interesting tables appended. Mr Stott has always said that his electric cable installation has given a most excellent performance and has even exceeded his original expectation. An examination of the first table will show that even during the year 1906 there was only about one burnout due to troubles, excluding the external causes, for about every 60 miles of cable. The best performance was one burnout in over 350 miles of cable. It is a well known fact that a short circuit on a large system like the one under consideration may cause an impulsive rise of voltage which is many times the normal voltage, hence as there were many burnouts from external causes the burnouts

in the cable proper may largely have been caused by the former.

HIGH TENSION CABLE BREAKDOWN SUMMARY.

January, 1904, to October, 1909—11 000 Volts.

Year	Miles of *Cable	In Joint	In Bend	In Cable	External Causes	Total	Excluding External Causes. Percent Per Year Per Mile
1904...........	330	1	0	1	1	3	.61
1905...........	351	0	0	1	0	1	.28
After Grounded Neutral Installations:							
1905...........	351	0	1	1	0	2	.57
1906...........	353	3	0	3	5	11	1.70
1907...........	353	1	0	0	5	6	.28
1908...........	368	1	0	0	4	5	.28
1909...........	371	3	0	1	4	8	1.08
Total		9	1	7	19	36	

External Causes—Mechanical Injury, Steam Leaks, Armor Burns from Other Cables.

Subway opened October 27, 1904—Road 25.63 miles in length.
Estimated daily maximum daily traffic—400 000 to 500 000.
Actual maximum daily traffic—1 179 000, 136 percent.
Actual weekly maximum daily traffic—7 515 635.
1906—First fiscal year, car mileage—31 931 072.
1909—Fourth fiscal year, car mileage—46 915 891, 46 percent.
Population Manhattan, Bronx and Brooklyn, June 30, 1904—3 535 642 (Est.) Health Dept.
Population Manhattan, Bronx and Brooklyn, June 30, 1909—4 076 883 (Est.) 15 percent.
1906—First fiscal year traffic—137 919 000.
1909—Fourth fiscal year traffic—238 430 000, 73 percent.
Traffic figures represent ticket sales.
Actual traffic, representing company employees, police, etc., add 3 000 000 to 4 000 000 per annum.
Passenger traffic per annum per mile—46 000.

Interborough Rapid Transit Co., Motive Power Dept.,
October 18, 1909. H. G. STOTT, Supt. Motive Power.

The second part of Mr. Stott's report is very interesting, and shows that the increase of the number of passengers could not be accounted for by the increase in population. In other words, people will patronize a good rapid transit system better than a poor one. I have often known people in Pittsburgh to walk home sooner than have to ride in crowded cars.

In the country back of Etna and Sharpsburg is a great deal of territory which could be used for residential purposes.

A farmer living there once told me that he had just papered a room which had not been papered before for 25 years. He said the paper was still clean, but he just wanted to make a change. Such a condition of freedom from smoke is almost inconceivable so near Pittsburgh. The flowers and leaves in this locality seem to retain their natural colors, which also indicates the purity of the atmosphere there. Now if it were possible to reach this district by means of a subway in 10 minutes from Pittsburgh, would not the ground become most valuable for residential purposes? A subway there, of course, would not pay unless the company building it could, in the first place, purchase at the present price of property large tracts of the most desirable land on which subsequent profits would be enormous.

President Barnsley: I take pleasure in requesting Mr. D. P. Black, Chairman of the Rapid Transit Committee of the Chamber of Commerce, to address us on this subject.

Mr. D. P. Black:* I came here tonight to learn a great many things about which I have been groping in the dark for the past 15 years, from you gentlemen who have been studying these matters for years and spending on them your money and thought. I had not the slightest expectation of being asked to say anything, but sometimes the outsider, the man who does not know much about a subject, can give a pointer or two to those better informed, because he is in a position to look at it from another point of view.

There is no question that something is vitally wrong and that something ought to be done. If I were going to try to work out this thing, I would like to get into Mr. Wright's flying machine and look out over the city in every direction and see just how you are going to get from one point to another.

In the first place, I would leave out every loop in this downtown district and run every car through from the East End to Bellevue, from the North Side to the South Side.

* President, the Real Estate Trust Co., and Chairman, Rapid Transit Committee, Pittsburgh Chamber of Commerce.

There are those who will tell me that a loop will serve better than through service. While I am not from Missouri, they will have to show me. We could take the four sides of some square and with through cars serve two lines of cars on each side. As it is now, if Mr. Barnsley wants to go from the Court House to the Engineers' Society rooms in the Fulton Building, he cannot do so without riding on two lines of cars and paying two fares, while it is only four good squares to walk. It is ridiculous not to be able to travel four squares without paying two fares. If we had through cars in every direction it would furnish complete service to this district and would also make enormous profits for the street car company. It would eliminate all the right angle turns, and you probably know what it costs to run cars around a corner, grinding the wheels and tracks, abusing the rolling stock and increasing the personal injury cases.

The street car people would, of course, file objections to running cars through, claiming it would cut off one fare from their receipts, but there is no reason why they could not charge two fares from Bellevue to Wilkinsburg, just as well as from town to McKeesport or from East Pittsburgh into town. At least 95 percent of the people coming in would get off downtown anyway; nearly every car running through would have two fares for the trip, and besides, the traffic they would pick up in this downtown district would make up many times what they would lose in carrying passengers across this dead line.

There is another section becoming very popular in Pittsburgh—the Bellefield or Schenley district. Several people went out to the base ball games not long ago. Besides Carnegie Hall, the Conservatory, the University, Memorial Hall, etc., who knows what we may have in that district in the not distant future? At present there are only a few people between the rivers who can reach that point with one fare. This city falls into three natural divisions—between the rivers, north of the river, and south of the river. About half of the population lives between the rivers. People from the North Side have just as much right to get to Carnegie Hall for five

cents as people from Wilkinsburg, and the street car company should be compelled to furnish some sort of through service. Then those who use local trains on the Ft. Wayne Railroad have to go to the Allegheny station. They are obliged to leave Carnegie Hall before an entertainment is half over, pay two fares, and then perhaps miss their train, and sometimes it is embarrassing to explain how one missed the "Owl Train."

I would think, therefore, that the first thing we must do is to regulate our surface lines to run clear through as I have indicated. Next, in regard to subways, we would have to be careful not to bind ourselves in the same way we did with the surface lines, that is, not to give any company a right to a downtown loop. It will prevent through traffic almost forever should such a right be granted.

I believe that there is enough population on both the North and South Sides to compensate for the extra length of road necessary to avoid downtown loops. If you were to build a tunnel on the lines laid out by some of the companies which have asked for a charter, you would go three miles before getting a single passenger. On the other hand, you could go to Allegheny and reach 100 000 at your first station, and on the South Side you could reach half as many in the same distance. Instead of making a loop, make a *Y* with one branch running under the river to the North Side and the other to the South Side, extending out on both these arms as far as the population would warrant, and you would obtain good through service, such as we have been talking about with regard to the surface lines. Until we get the people educated up to that, however, we are going to have trouble with all the companies asking charters for a loop. It is all right to talk of it from the financial standpoint, but the people ought to look out for their own interests and not bind themselves as they have done before. I do not know that I would venture to voice such a complete idea for steam railroads, but 20 years ago I advocated running steam cars through in the interurban service, as they are now doing in a few instances on the Ft. Wayne and the Pennsylvania roads.

These are only a few of the ideas I have had on the

subject, expressed in a very crude way. If the engineers would take them up, or something along these lines, improving on them and working out details, I think the City of Pittsburgh would be somewhat benefited thereby.

President Barnsley: I see with us a guest who has given a great deal of attention to at least one phase of the question of rapid transit, the matter of a tunnel in order that the people of the South Side may reach the city quickly, and I will ask Mr.. Frank Gosser to say something to us.

Mr. F. I. Gosser:* The remarks of Mr. Black are worthy of your careful consideration, and though his language, like my own, is impromptu, yet his position as head of the Rapid Transit Committee of the Civic Commission of this city indicates that they are the product of much careful thought expended on the subject we are considering.

I am convinced that the very best encouragement that can be given towards the solution of the rapid transit problem in this city is this meeting itself and the legitimate effects of it. The fact that the subject brings together such a large representative gathering of scientific men, testifies your devotion to public welfare and your purpose to contribute your technical knowledge to its advancement. Without overpraising, I may say that if the engineers of Pittsburgh give to this subject their recognized intellectual ability and concentration of mind, the difficulties will be solved. I do not here suggest specifically what is, to my mind, essential to bring about an amelioration of the conditions of the inhabitants of this city with respect to the street car transportation problem. I do most seriously, however, regard that there are great humanitarian and moral elements involved. I regard the possibilities of our people, their hopes and purposes as American citizens being comprehended in the right solution of the rapid transit problem, and I believe, if there is any association in the whole world the life and training of whose members is likely to endow them with the ability to cope with the exigencies of a complex situation, it is the engineer-

* Attorney, Frick Building; President, South Hills Board of Trade.

ing profession. I do not assume either to interpret or to instruct you in the scope and ethics of your profession, but I trust I shall not be criticised when I declare that it is my frail opinion that your membership in its personality has been entirely too modest. You have withheld yourselves from the practical activities of the world as you ought not to have done. You have rather been the servants of great achievements; you have waited patiently or impatiently in your offices, and, apparently bound by forbidding ethics, awaited the commands of the so-called captains of industry, and carried into effect really great miracles of scientific achievement, for which you have not received acknowledgment, and thus occupied, in the annals of accomplishment, secondary place to men of less talent than yourselves.

I have advocated, and I wish to present here, that our form of government is surcharged in the way of executive offices. I believe we should have an office of initiative, that is, a Board of Initiation to suggest to the people improvements in their respective communities rather than to have projects made a reality after a half century or more of complaints to executive officers. In such a body or board to suggest improvements for the public welfare I can certainly think of no one profession better equipped than the engineering one to bear a large part.

You gentlemen of the engineering profession recognize that it is entirely within your province, and it is your duty as a large representative, intelligent, patriotic body of men, to suggest projects looking to the public welfare. In so doing you will be called upon to become well acquainted with the geographical, topographical and physical conditions of the community; to gather data as to the nature of local grievances, and, with your splendid minds, to demonstrate to the executive functions of government the benefits arising through certain practical material changes and improvements. I might suggest as a strictly local illustration, that the Smithfield Street bridge, now about to be widened, continued for many years in an unsatisfactory condition; street cars required five or ten minutes to cross, and patrons of the Pittsburgh &

Lake Erie Railroad were held up and missed their trains on account of the inefficiency of that structure. The complaints were numerous, but badly scattered, and the complainants were not organized, and so this bridge highway bid fair to continue at least partly as an obstacle, rather than as an agent, to public travel for many years yet to come.

The organization, of which I am for the time being the head, recognizing the unfortunate conditions existing on that great highway, took up the matter; our start was by writing to Col. Schoonmaker, the local head of the Pittsburgh & Lake Erie R. R. He answered me that he had no adequate words in which to express his gratification that some effective organization was taking up that subject. We then invited the attention of the Mayor and the Pittsburgh Railways Company to a meeting, and it was only a few months until the plans had been worked out and official directions given for the improvement.

Now it appears to me that there was no reason why the engineering profession should not have been first to discover that evil and as easily have fathered the beneficial accomplishment. This city is your own by the highest behests of patriotic inclination. You should take a part in the advancement of it, and then, too, it would mean from a financial standpoint new and profitable business to your profession. In other words, our form of government can well model itself after the structure of the natural body: One part of government to typify, so far as material improvements are concerned, the brain, that conceives; another element in government to be the executive, to carry into effect the conceptions of the mind.

Why should not the engineering profession symbolize the brain organism in government so far as relates to material improvements? A body of engineers should traverse this entire community and meet the residents of the various localities, and discuss their needs with the people. They would shortly be able to suggest to the executive functionaries marvelous improvements that would redound glory to your profession and infinite blessings to all the people.

What I am attempting to convey to you is that I feel your modesty, or the ethics of your profession, limitedly interpreted, deny to you the maximum of opportunity for good both to yourselves and to your constituencies. Think of the great City of New York and those magnificent improvements lately brought into realization. Think what a wonderful part the engineering profession had to do in carrying into effect the brilliant ideas, persistently advocated by a humble young lawyer from Tennessee, almost friendless in that great metropolis. It is said that Mr. McAdoo, almost against the dictum of engineers and in spite of the paucity of financial support, through the buoyancy and yet sanity of his enthusiasm, wrought out those wonderful marvels of practical good to the people of New York.

The engineering profession, had it regarded the initiation of such projects and advocated them with incessant zeal, would have come into its own and would have discharged, it seems to me, the legitimate mission of the profession. The illustration of Mr. McAdoo's magnificent genius and audacity in behalf of his splendid projects, must not be disregarded. If I can, I wish to inspire you with the courage that knows no resistance, and like him, bring about in the way of a transportation system for this city, wonders not yet heard of, but certain to be realized through concentration of your disciplined minds and energy.

I believe that much good will be accomplished if we take upon ourselves the thought and obligation of responsibility; that these great material effectuations become spiritual and moral contributions in the making of the world; that they are not for the other fellow to imitate, but that the grand projects we have in mind, and those yet unborn, for the benefit of every man, woman and child in this city, is upon each of us, and I certainly feel that the grave yet welcome responsibility rests on the individual make-up of this splendid gathering.

Mr. F. W. Winter: It occurred to me as I listened to the discussion that we cannot have anything like rapid transit with surface lines on our narrow streets and sharp

curves. Therefore, it would seem to me a waste of time to attempt to improve on these conditions except for local traffic and as feeders for some rapid transit lines. Furthermore, if our newspapers can be believed, the efforts our Mayors have made in the last few years to induce the Railways Company to better conditions, show conclusively that this is not a very fertile field to till. The Engineers' Society should take a more radical stand. We should not merely attempt to alleviate conditions as they now are, but we should try to solve the problem for 20 years in advance; and I believe the only solution for the future is either overhead or underground systems. I advocate underground systems as far as possible, and agree with Mr. Moore that it should be a system which, for a large part of its course, would have four tracks, two for express service and two for local traffic. I also agree that it would be too much to expect the Railways Company to furnish the capital for such an undertaking. I do not advocate a terminal down town, but believe with Mr. Black that we should as far as possible strive to get through lines with a *Y* down town. I do not believe that very much could be gained by an attempt to widen the streets. The dangers due to vehicles and teams would always be sufficient to cut down speed. Besides, if we should widen enough streets to get substantially better conditions in the congested sections, we might as well put that money underground or overhead and build something permanent for the future.

This is a question in which not only engineers, but every citizen, should take active interest, and I think we should build not only for today, but for the future.

Mr. W. G. Wilkins: Attention has been called to the delays and interruptions to street car traffic caused by vehicles getting on the car tracks ahead of the cars and holding them up while the teams pull out to let the cars pass. This could be avoided to a considerable extent on some of the Pittsburgh street car lines, if vehicle traffic could be regulated on a similar plan to that adopted in Philadelphia on Chestnut and Walnut Sts. The vehicle traffic is only allowed to go east on Chestnut

St. and west on Walnut St. If a team coming from West Philadelphia wants to reach a point on Walnut St., say between 10th and 11th Sts., it must be driven east on Chestnut St. to 10th St., then cross over to Walnut St. and go west to the place of destination, or if a teamster starting from a point on Walnut St. wants to reach a point on Chestnut St., say between 14th and 15th Sts., he must drive west to 15th St., on which he crosses over to Chestnut St. and then east to the place he wishes to reach.

By this method all vehicle travel on these streets proceeds in one direction only, on both sides of the car tracks, consequently there is not the interruption to street car traffic that there is when vehicle traffic goes in both directions on both sides of the car tracks. In the latter case the cars are frequently held up by teams going in the opposite direction from the cars having to pull on to the car tracks to pass teams going in the opposite direction. While the plan met with considerable opposition in Philadelphia when it was first put into effect, it has resulted in very much less delay and enables the street cars to make much better time than formerly, and all opposition from vehicle owners has disappeared.

This method of regulating traffic might possibly be adopted in Pittsburgh to regulate traffic on Liberty and Penn Aves., say as far as 33rd St., the vehicles on Liberty Ave. to travel west, and east on Penn Ave. It could also be applied to travel on Fifth Ave. and Forbes St., as far as Boquet St., going east on Fifth Ave. and west on Forbes St. It would seem as if this plan would accelerate not only street car traffic, but also vehicle traffic as well.

Mr. E. K. Hiles: While, as a previous speaker has pointed out, rapid transit in the true sense of the term can be secured only by lines either elevated or under ground; yet it is believed that present conditions on the surface car lines could be much improved while we are waiting for rapid transit to become a fact.

Traffic conditions on Forbes St. and Fifth Ave. might be vastly improved, so far as quicker service to the East End

and points beyond is concerned, by having through cars only on Forbes St. running without stops between Grant and Craig Sts., and using Fifth Ave. for cars making local stops. This service might be still further improved by the addition of "trippers" on Fifth Ave. during the rush hours, which cars could be run out as far as the Schenley district and looped back via Center Ave., the loop being made preferably on Dithridge St., or some street other than Craig in order to avoid running additional cars on that street.

As a means of saving the time lost in making stops at practically every cross street, as is the case on portions of some lines during certain hours, a rule might be put into effect fixing stopping points at every second block, which would not prove a hardship to the public in view of the quicker service obtained.

It is realized that the state and city authorities would have to make certain agreements with the Railways Company, owing to requirements in the various charters under which the company operates; but it is believed that such agreements would readily be entered into by the authorities to permit these traffic regulations being put into force as well as other desirable changes.

Doubtless other reasons might be advanced by those directly concerned in the operation of the street car lines, suggested by their wide experience, which might indicate a lack of feasibility in some of these suggestions; but no objections should be allowed to be insurmountable in the matter of providing quicker service at once on the surface lines.

Mr. Geo. S. Davison: I would have preferred to have been a listener tonight, as I did not come prepared to speak upon the subject. The difficulty in my attempting to say a little upon it is, that I have so much I would like to say and I cannot say it logically and in proper sequence without preparation. Perhaps at some future time I can lay before the Society some of the points which I am bound to omit tonight for lack of time.

The rugged character of our local topography, and the narrowness of our highways, present unusual obstacles to the

construction, operation and maintenance of any system of railways, whether they be surface, overhead or underground. Assuming that as engineers you will appreciate the full meaning of this statement, I do not feel that I need elaborate upon it, at least so far as the question of construction is concerned. With an unlimited cash account to draw upon to carry forward a work of construction, almost any one of intelligence will succeed in overcoming the physical difficulties that present themselves, but it requires the skill of the engineer to determine to what extent cash should be the debtor to construction, that a sufficiently good result be had with a reasonable expenditure of money. And if the cost of the construction be in the form of an investment, the returns upon which must, in addition to operating expenses, be a certain percentage per annum of the investment, the engineer must be relied upon to determine the desirability, from the investor's standpoint, of entering upon the work.

The question of rapid transit for Pittsburgh must be approached by the engineer not only with the full appreciation of what has been said about the topographical obstacles to an economic construction, but it must be recognized that these conditions of topography will have a very depressing effect upon the income of the venture, even though the system produced be a triumph of "mind over matter."

Any of you who are familiar with every nook and cranny of this city, and who feel competent to picture in your mind's eye the appearance of any and all parts of this city, will be surprised with the results if you take a map of Greater Pittsburgh and undertake to outline thereupon the relative densities of population of various parts of the city. You will find an immense amount of territory that can never be utilized for dwelling or business purposes, and what portions of it are now utilized do not form a compactly built and continuous area. Then just recall to mind, for the sake of comparison, the parts of New York, Chicago, Boston, London and Paris that are served by underground or elevated systems of transit, and bearing in mind that these cities have, unlike Pittsburgh, besides their own population, immense numbers of transients

within their limits at all times to help street car traffic, you will at least arrive at the conclusion that the underground or overhead methods of transit in Pittsburgh are very different problems from those in the cities mentioned.

What is this thing we call rapid transit? In the last decade it was probably the electrically propelled street car. This decade it is a dash beneath the city's sewers. Next decade, and I am mindful that we have air ships with us, it may be a system very similar to our telephone system, and comprising instead of wires large pneumatic tubes. Home and office will have installations in the form of receptacles large enough to take in the human form. Should we want to go from our house to our office, we tuck our long chin whiskers beneath our collars, step into the receptacle, make our destination known to those in charge of the switchboard, and in less time than I am taking to tell it, we will be shot into our office chair ten miles away. As just intimated, the popular notion at present is, that rapid transit is a subway, and that we must have it at any cost.

For my part, I do not think Pittsburgh is ready for a subway, if the money necessary for its construction and equipment must be considered in the light of investment. If some public benefactor can be found who will make us a present of an up-to-date underground plant ready for operation, I think it would be a good business stroke for the city to agree to have it operated for the benefit of the public without further expense to the aforesaid benefactor. Otherwise I think we should approach the subway era of things with some thought as to the financial outcome. When we come to think it over, it is not so much speed that we need. If we are journeying to New York the saving of 10 percent of the time it takes to make the journey, or say one hour, is of some consequence. If we are going home in the evening on a street car that ordinarily will require 30 minutes for the trip, how unimportant is the saving of six minutes, which is twice the ratio in the above journey or 20 percent, if we travel comfortably meanwhile and without delay. To my mind our problem is the elimination from our streets, and from the operation of

our present system, everything that means delay. This is a very simple form of speech, but underneath it are so many questions to be settled that I hesitate to enumerate them at this time. One of these, however, would embrace the rearrangement of the present tracks in the down town district, and even to the extent of abandoning some of them. These tracks are not owned by the present operating company, and under the leases by which they are held, the franchises permitting them to be built and operated must be protected by continued use. To change or annul these franchises, the corporations owning them, the commonwealth that created the corporations, and the municipality that granted the rights to occupy the streets, must agree upon a plan of procedure. Such an agreement would be no small accomplishment.

Assuming that this were legally possible, I believe the simpler and most effective arrangement of the tracks in the business district of the city would be to have four loops occupying the four streets surrounding one of the more important and favorably situated blocks of this district, these loops not intersecting each other, but being capable of being connected, so that some lines, other than the looped ones, could be operated between certain sections of the city, and make use of the loops contiguous to the block selected.

Wagon traffic should as far as possible not be allowed to interfere with street car traffic. I believe it would be just as sensible to have a subway under one or more of the busy down town streets, so that the through wagon traffic could be taken off the streets , as to consign the passenger traffic to a subway. At any rate, the police power of the city could be used to a considerable advantage in having teamsters show a higher regard for the rights of the people who travel by trolley car.

Improving the facilities for passengers to get on and off the cars, and reducing the number of stops about 25 percent by the Railways Company, and the cultivating by the passengers of a higher regard for the rights of their fellow passengers would combine to cut down the time necessary for a trip by street car and leave the impression with the passengers taking

the trip that the time occupied seemed no longer than it actually was.

Mr. Morris Knowles: Our President has certainly used his prerogative extensively in calling upon members unexpectedly. I believe in the old adage, "Let not the cobbler go beyond his last," and, although somewhat familiar with the hydraulic and sanitary problems of this district, I do not profess to be able to contribute to a technical discussion of the traction situation; but, if I may be permitted, will give some thoughts which upon similar problems have seemed worth while.

I would, above all, suggest the idea of a broad consideration of this whole question. This it seems to me to be the most important, and we should not magnify our preconceived notions in regard to little inconveniences and disregard, for the time being, the little discomforts that affect us as individuals from day to day; for, if we do not do so, we are likely to get a biased view and forget the view point of the other side, which is very necessary in a thorough study of any problem. The Engineers' Society can take a prominent step forward in this matter, by making an appeal for this thorough study and in upholding the hands of and requesting that other bodies having influence and of like minds shall take this matter up with the intention of considering all the matters that enter into it; and with the attempt to not only solve the present pressing needs, but look into the future and determine policies and plans for extensions for the best service.

While we may believe that the traction companies, and even other public service corporations, have brought upon themselves, to some extent, the unpleasant conditions that exist, we must certainly acknowledge that they have their view points as well as the people and the city authorities. Street railways are not built for love, nor because of public sentiment or public spirit, but for the purpose of making money. It is true that it pays sometimes to build lines into districts where traffic is not yet developed or plentiful enough to pay, but in these instances it is expected that, in a reason-

able number of years, the growth will make such a line pay. These development charges should be borne in mind, in considering a proper recompense and whether it is proper to demand additional facilities. It is true, also, that the education of the people in regard to what reasonable facilities are, and about the regulation of vehicle and other traffic in order to permit more rapid movement of cars, is a wise and necessary step and something that we or the city authorities should do to make possible the complete utilization of present facilities.

We have seen examples of institutions which have apparently been helpful in solving these problems, and I believe that Public Service Commissions, such as exist in the states of New York and Wisconsin and the city of Chicago, have done much to bring about better conditions. An improvement of facilities has certainly been brought about, and I understand also, that corporations themselves feel that there is a certain permanency of policy about the matters of traffic, compensation and other details which, when regulated by such a commission, are not going to be upset by each incoming administration, or particular whim of a new man in office; therefore, they feel that they can, with greater certainty, project and plan for the future. Some official body having similar comprehensive and adequate powers should be provided to deal with our traction situation.

Thus I repeat, that while these complaints are examples of the failure to meet the public needs, we should not magnify them to the extent of forgetting the view point of the other side and the broader outlook and, if possible, let our Society stand for the policy of, and by co-operation with other bodies to seek for, an exhaustive investigation into the whole matter.

MR. N. W. STORER: It seems that we have left out of consideraton the great assistance the steam roads can be to the city in handling our local traffic. If the Pennsylvania Railroad, for instance, were given proper facilities through the city, it could serve an enormous area of the city and serve it exceptionally well with the electrification of the roads

which will undoubtedly come in a short time. And I believe the trackage they have is better fitted for it than any subway system would be for a number of years to come. We could probably build a subway to the Schenley district, but it is questionable in my mind whether a subway to Wilkinsburg or beyond will pay. I believe in a subway, however, for the down town district. But consider what can be done with our steam roads. The Pennsylvania System includes not only the lines east, but the Ft. Wayne, the Panhandle, the P. V. & C., the West Penn and the Allegheny Valley, reaching all sections of the city. I do not believe in forcing them to electrify at once, because it is too big a problem to undertake in a short time. But if they were given some inducements to provide their lines with proper facilities for handling this traffic I know they could do it to very great advantage.

Mr. H. S. Anderson: When the physical conditions under which the Pittsburgh Railways Company operates are considered, I believe that company is giving the residents of Pittsburgh good car service. In considering this rapid transit proposition, too many people confine their attention to the Point District, and overlook the fact that there are vast property interests on the northern side of the Allegheny River that could be improved.

About the only way the surface cars could give better service than they do is by running all cars to Allegheny, and by using a "hub" say at the square bounded by Federal St., Lacock St., Anderson St. and the Ft. Wayne tracks.

A subway suggests to me the only method by which we can obtain rapid transit. There should be two separate systems controlled by one company, with a central station located on the square bounded by Federal St., Lacock St., Darragh St. and the Ft. Wayne tracks, adjacent to the "hub" proposed for surface cars. These two systems I will call East Street Banksville, and Penn-Fifth. Both should be two-track systems.

The East Street-Banksville system should commence at East St. and Perrysville Ave. and follow East St. to East

North Ave., thence diagonally to the proposed central station, from there along under Lacock St. to South and Allegheny Sts., under the Monongahela River directly under Grandview and Republic Sts. to Cynthia St., to Banksville Ave. and thence to Mt. Lebanon.

The Penn-Fifth system should follow Fifth and Penn Aves. until the city is reached, passing under the Court House to Third and Penn Aves. and around into the central station at about School and Lacock Sts., thence to Grantham and River Ave., across the Allegheny River to 12th and Etna Sts., to Penn Ave. Traffic on these lines should always be to the left and both systems can be connected. Traffic coming down East St. can be turned by a *Y* onto the Penn Ave. outbound track. Traffic from Banksville inbound can be turned in the same manner to the Fifth Ave. outbound track, and so on.

This system is proposed on account of its practicability and as the cheapest.

The Penn-Fifth route will practically be all underground, but the East Street-Banksville route will only be underground from East North Ave. to Cynthia St. It could run along the hill, and after coming out at Cynthia St. it could run in the open following the Banksville macadamized road to Mt. Lebanon.

There is no question but that the population of Mt. Lebanon and the district bordering on Perrysville and East Sts. will grow, and such a system proposed will be the most advantageous of all.

The central station will receive a lot of traffic from the Federal St. depot, and the Penn-Fifth route will receive a large amount of traffic from the Union depot.

Mr. C. B. Albree: The city of Paris is in some ways like Pittsburgh, as it is divided into two parts by the river. They built a subway from one extreme end of the city to the other on one side of the river only. The traffic changes almost entirely in the middle of the city, as Mr. Black suggested. There are very few through passengers. There is a thickly settled residence region at each end of the line and a

business section in the center, and it seems to me that part of his suggestion is very good whether we have a subway or a surface line. In Paris they have since added to the subway, various others covering every part of the city and connecting with this main route, so that Paris today is the most accessible large city I have ever been in.

MR. R. C. WOOD: One of the first things that should be done in the interest of rapid transit is the elimnation of grade crossings, which are not only a source of danger and delay to street car traffic, but to all who in any way have to use them. There are but few of them in the city, and these few should be gotten rid of immediately.

MR. L. P. BLUM: The most dangerous sentiment possible to express is that we are no worse off than other cities. Even if this were true, which is doubtful, it furnishes no excuse for present conditions. Progress is always the result of discontent with existing conditions, and if Pittsburgh is to continue to progress as a commercial and manufacturing center, she must progress in transportation facilities also. If our city is to continue to hold its preeminent position in business and manufacturing, it must furnish the best possible living conditions, for its manufacturers, business men, clerks and artisans. We must insist that our public service corporations keep pace with the progress of our business and manufacturing interests.

It is doubtful if very much improvement could be made in our surface conditions by a widening of streets in the congested area as has previously been suggested. Any general widening of streets is such an extremely costly matter as to be impracticable. The simple addition of five feet to each sidewalk of Chestnut St., Philadelphia, for about four blocks in length, involved land damages of over $200 000.00. An examination of the original plan of Pittsburgh will show the remarkable fact that in a period of over 100 years there was not a single change in the lines of any of the streets or alleys from that shown on the original plan; and it was only through the generosity of a single citizen and property owner that

the city during the last five years has felt justified in widening two streets for a length of two blocks each. Cecil Alley is the only street in the original plan that has been widened entirely at public expense. The continual increase in property values in all business centers is making such changes more and more expensive. In view of these facts, the writer believes that the width and location of our streets in the congested area are established for all time.

Much could, however, be done by police regulation to increase the carrying capacity of our streets, as for instance, the Philadelphia plan outlined by Mr. Wilkins. From personal observation, the writer believes that this plan greatly aids traffic along Chestnut and Walnut Sts. A similar regulation of traffic on Fifth Ave. and Forbes St. would seem to be the best test of the value of such a system, and a further regulation, that no vehicle should be stopped on the south side of the street devoted to east bound traffic, and vice versa, except during the time necessary for actual loading and unloading, might help conditions.

Indeed, it seems to the writer that a disposition exists among vehicle owners to use even the most crowded city streets as a storage room. While a moderate use of city streets in such a manner is perfectly proper, there is no good reason why vehicle owners should be allowed to have their vehicles standing on our most crowded thoroughfares for hours at a time. This condition of affairs has frequently come to the writer's attention.

But, after all possible remedies for surface congestion have been applied, we are face to face with the fact that the time is at hand when some other than surface transportation is necessary to meet the growing demands of the greater city. And by the logic of facts, we are driven underground. Private surface right of way is too expensive, if at all practicable. We have no streets wide enough for elevated roads, even if there did not exist a prohibitive public sentiment against their adoption. What shall be the character of such a subway? Upon the one hand, some experts tell us that no subway will be a profitable financial investment; upon the other hand,

some favor the building of four tracks to the East End and the immediate provision of subways for the North and South Sides.

The writer believes the latter program to be too ambitious. Whether a subway is built by private or public funds, it would be folly to invest millions in a form of construction which would not be required for many years to come. A system should be adopted which will take care of the needs of the present and immediate future, and which shall still contain within itself the power to expand as conditions demand such expansion. The writer believes it possible to design such a system. Based on the operation of subways in other cities, there is at present no section of our city sufficiently densely populated as to require subways, except the East End. The writer believes that a properly constructed two-track subway, with a central loop, one side of which should be preferably along Liberty Ave., will take care of the traffic for years to come. We must be careful on the one hand not to mortgage the future resources of the city by an extravagant and unjustifiable expenditure, nor to perpetuate the present evils by recommending a program of improvement which would scare our citizens by its extravagant cost.

It matters very little whether the city owns the subway or grants a franchise to build one, under proper restrictions, to a responsible corporation. Due to our past unfortunate experiences, today the public are clamoring for the municipal ownership of all public utilities. In the next decade they may demand that such utilities shall be administered by public service corporations under proper restrictions. In either case the same principle prevails; neither municipality nor corporations can afford to operate for any long period at a profit less than the cost of fixed charges and interest on the cost of construction.

A NEW TYPE OF WATER TUBE BOILER

By T. H. McGraw, Jr.*

We are all familiar with the various ways by which water is converted into steam. In view of the present tendency in modern power plants to use high pressure steam, it is my intention to discuss only the water tube type of boiler, which is the only type truly adapted to high working pressure with safety. The reason for this lies in the fact that a properly built water tube boiler is a combination of small elements, each carrying a comparatively small amount of water and each, on account of its small size, being easily designed to withstand a high working steam pressure without unduly increasing the thickness of the containing walls; in fact, reducing the thickness of the walls to the minimum consistent with safety and thereby permitting a very much freer absorption of heat than would otherwise be possible.

The marine and return tubular types of boiler are exactly opposite in this respect, as they deal with a containing shell or element of large diameter, which must consequently be constructed of very thick material in order to withstand the high tensile strain to which it is subjected in the event of high pressure steam being desired. This thick containing sheet is slow to transmit the heat generated in the furnace and has a tendency to burn on the side exposed to the fire which is removed from intimate contact with the cool water in the boiler by the thickness of the plate in question. The burning of the plate reduces the tensile strength of the shell and gradually an element of danger is introduced with this type of boiler.

Considered from the standpoint of safety, the water tube boiler has all the argument on its side. Let us assume that one of the tubes of a water tube boiler directly over the fire

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* Manager, Erie City Iron Works, Pittsburgh.

and doing the most work lets go. At the maximum this tube would be only four inches in diameter, and the result could be compared to the opening of a pop safety valve. The water would put out the fire and the boiler would have to be taken off the line until a new tube was inserted. If a point right above the fire in a shell boiler is considered, which point is doing the most work and most apt to give way, and an explosion is assumed, instead of a four inch rupture, a rupture of the full shell diameter occurs, invariably resulting in the entire destruction of the boiler house and probably a loss of life.

The high working pressure at which boilers are now operated is almost a necessity when viewed from the standpoint of the cost of the power generated, as the efficiency of a condensing, compounded non-condensing, or superheating operation depends very largely upon a high initial steam pressure. Furthermore, the size of steam lines, engine cylinders, foundations and floor space are reduced, resulting in a smaller building being required, so that not only are more economical results secured after the plant is started, but the initial cost of the plant is reduced by the use of high pressure steam.

Regarding some of the most important points involved in the design and construction of the water tube boiler, the necessity for active and thorough circulation of water through the boiler parts exposed to the fire and heat is of prime importance. The tubes of a water boiler contain a comparatively small amount of water, and when it is considered that this small tube is enveloped in a temperature ranging eighteen to twenty-five hundred degrees, it is readily seen just how long the water in the tube would last if there was not continuous circulation through the tube. If the water does not circulate large pockets of steam are formed which rise at intervals and liberate badly, causing much entrained water in the steam. Furthermore, the formation of the pocket removes the cooling effect of the water from the tube, which causes a blistering and warping of the tubes. A quick, active circulation through the tubes or parts of the

boiler exposed to the heat and flame contributes very largely to satisfactory operation. As soon as a small quantity of steam is formed in the tube, the circulating current carries it to the liberating surface, maintaining a constant supply of the steam generated. The circulation further assures the presence of water in the tube at all times, thereby keeping the tube at a cool, even temperature and eliminating the tendency to warp, blister or to sustain uneven strains. A good circulation in the boiler, therefore, contributes very largely toward dry steam and the life of the tubes, as well as obviating the danger of strains due to unequal expansion and contraction.

The next feature of importance is the proper construction of the furnace and baffling, so that the largest amount of heat shall be liberated from a given amount of combustible and made available at the proper time for the full absorption of the heat units contained.

It is not my desire to get into the question of stokers, but to simply mention the necessity for constructing a furnace in such a way that the cold tube surfaces are kept away from the fire until the process of combustion has been sufficiently advanced so as not to be affected by such contact. In other words, burn the fuel and liberate the heat units first and bring them in contact with the water surfaces afterwards.

Another feature absolutely essential to the successful operation of a water tube boiler is that ample opportunity be given for expansion and contraction. If opportunity for expansion is not permitted, strains are placed upon the tubes and tube sheets which invariably give trouble. One tube will occupy a hotter place in the flame travel than some other tubes, and there will be an unequal expansion or contraction due to these conditions in temperature and the design must permit this expansion and contraction to take place without bringing internal strains upon the boiler proper, or upon the brickwork, and without changing the position of the main steam outlet, as this would bring strains upon the the piping connected thereto.

The boiler that will meet these conditions in the most direct and simplest manner will give the highest efficiency, and I believe that the new vertical water tube boiler under discussion this evening, shown in Fig. 1, embodies a very large proportion, if not all, of the required features.

The circulation of water is brought about by the difference in temperature between the front and rear banks of tubes. The heated gases coming from the dutch oven extension furnace rapidly generates steam in the front bank of tubes, which rises, pushing the water in each tube ahead of it and drawing water behind it until the steam is liberated in the upper drum. It is now necessary to provide for completing the circuit by getting this water from the upper drum down to the lower drum. In the three pass boiler, shown in Fig. 1, it is difficult to say how many tubes in the middle bank have an upward and how many have a downward circulation. It is probably true that the tubes near the side walls and somewhat out of the line of travel of the hottest gases will not generate as will some of the other tubes directly in the travel of the hot gases, so we may conclude that the circulation is in part upward and in part downward in this central bank of tubes. In the rear bank of tubes, however, there can be no doubt that the circulation of water will be downward, for the reason that the gases in this third pass of the boiler have been so reduced in temperature as to preclude the possibility of generating any appreciable amount of steam. The flow of water will, therefore, be downward in the rear bank to supply the upward current created by the circulation in the front bank of tubes. Therefore, considering the middle bank as neutral, we have a complete circuit, the water flowing up in each of the tubes in the front bank, discharging into the drum and thence down the rear bank into the bottom drum. It is of value to note here that at no point in the circulation is there any contraction in the cross sectional area carrying the water, the full sectional area established in the front bank of tubes being maintained in the top drum, the rear bank of tubes, and across the bottom drum. This is in distinction from some of the other types of multiple drum

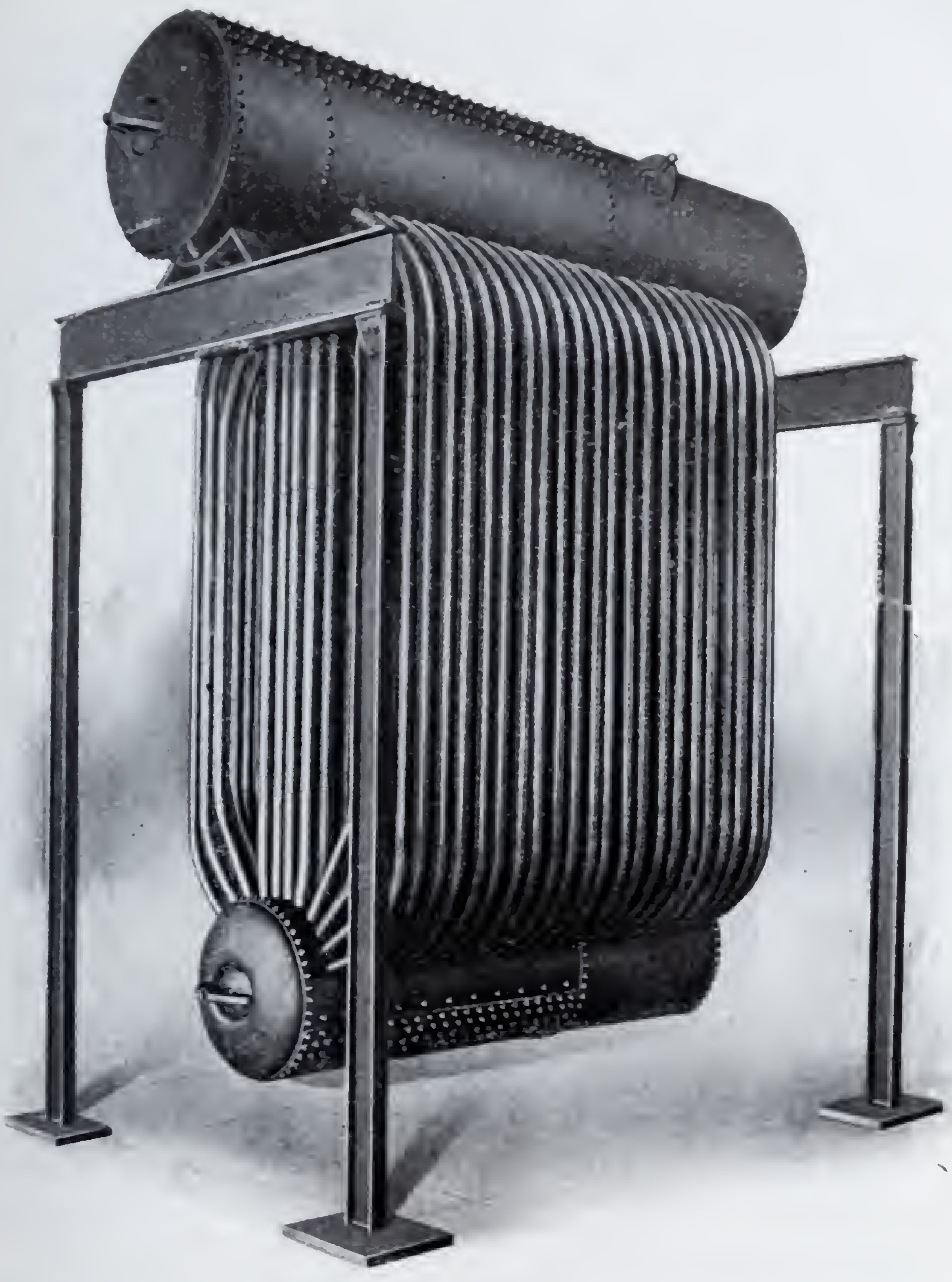

Fig. 1

boilers, where it is necessary to connect the drums by circulating tubes, which by reason of the fact that they reduce the cross sectional area, retard or throttle the circulation sometimes almost to a point of stagnation.

The water holding capacity of a water tube boiler must be in proper proportion to the steam evaporated, which matter has received careful consideration in the design of this new type. Figuring the cubical contents of the lower drum of the boiler under consideration, it is found that twenty-five

minutes are required to evaporate one-half of the water of the lower drum when the boiler is working at its rated capacity. This I consider a very good proportion to maintain, as too much water holding capacity relative to the heating surface, or horse power, results in a sluggish response to firing when peak loads are encountered, and too small a water holding capacity results in inability to maintain steam pressure under sudden loads on account of too small a reserve reservoir for heated water. These boilers are designed on a rating of 10 sq. ft. of heating surface to the horse power.

The furnace for the boiler under discussion is shown in Fig. 2, and is simply a good sized dutch oven carrying a heavy arch, there being two ovens for each unit. Two ovens are used in place of a single large one, in order to bring more heated firebrick surface in contact with the combustible gases and also to eliminate the tendency of one wide flat arch to caving in. The dutch oven, which is constructed of ample proportions, brings the gases of combustion in contact with practically an incandescent arch, and promotes the combustion to such a point as to liberate all of the heat units before any of the gases are brought in contact with the tubes. The result is better combustion, less smoke and a much higher efficiency than is possible where the partially burned gases are brought in contact with the water surfaces, which on account of their low temperature so reduces the temperature of the unconsumed gases as to prevent a thorough burning of the small particles of unconsumed carbon given off by the fire.

The heat liberated in this way is confined to the front bank of tubes by baffles rising on the bottom drum and carried upward to within a short distance of the top drum. The flame travel is then downward through the center bank of tubes, being confined by a second baffle, and upward through the rear bank of tubes to the stack which is located at the top.

A unique feature has been introduced for securing dry steam. It has often been noted that if the main steam nozzle of the boiler is placed directly over the liberating surface that considerable amounts of entrained water are present,

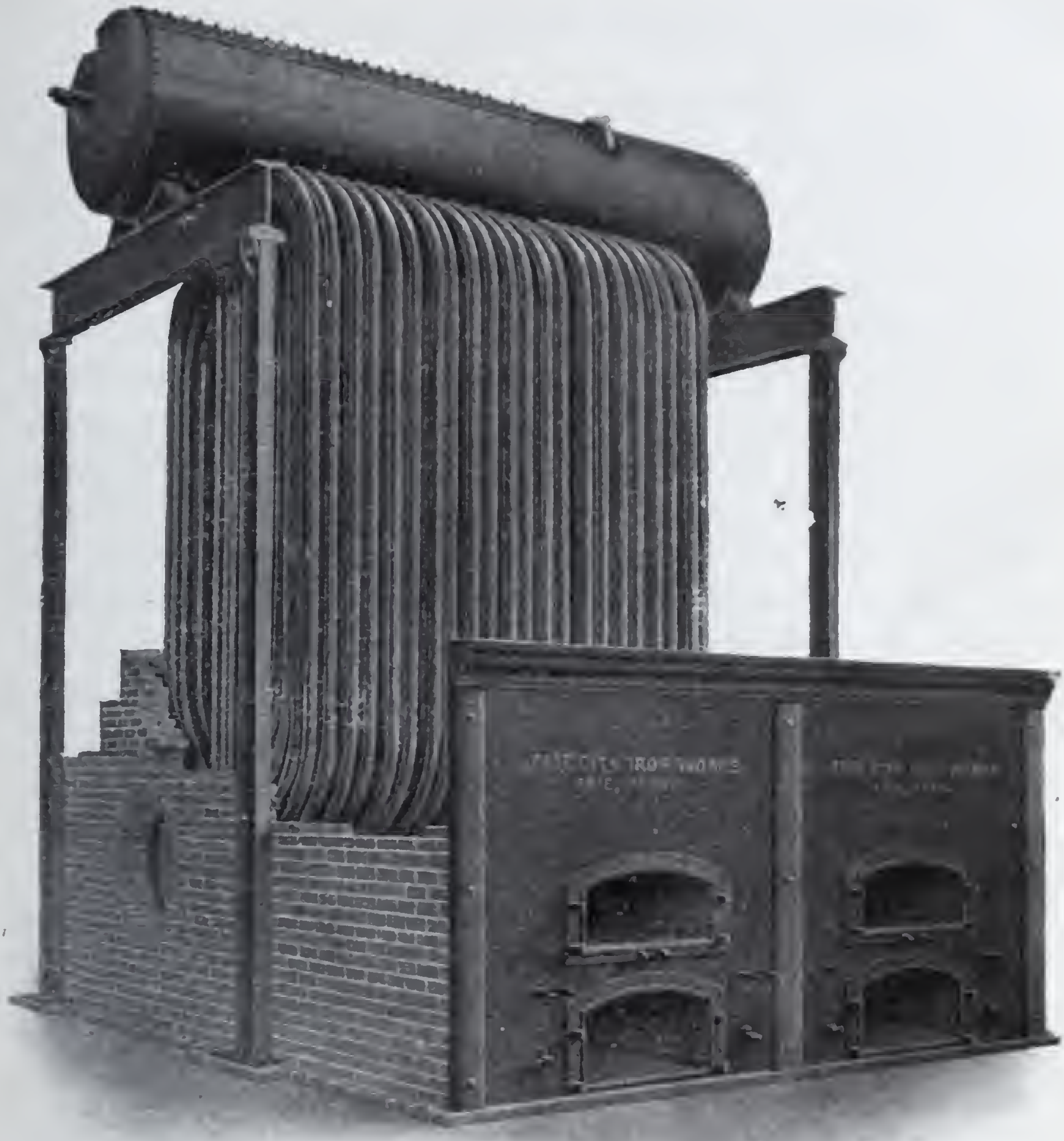

Fig. 2

resulting in wet steam. In the boiler illustrated the steam is not taken off over the liberating surface, the construction being as follows: The top drum is about six feet longer than the bottom drum, overhanging the bottom drum on each end by three feet. A water tight diaphram is placed so that the overhung portions constitute large steam reservoirs or horizontal domes communicating with the main section of the drum only at the top. A dry pipe is hung inside of the drum connecting these reservoirs and opening into the main steam outlet, which is located at the center of the top drum. In this way the steam generated accumulates in the main

reservoir of the upper drum, passes over the top of the diaphrams into the horizontal domes and thence through the dry pipe to the main steam opening and header. The efficiency of this device was well demonstrated in some tests which I witnessed in which the boiler was first operated without diaphrams or dry pipe, with simply the main steam opening on top of the upper drum. The boiler was run for ten hours for capacity test and developed 110 percent overload with a moisture in the steam, showing by throttling calorimeter of 2½ per cent. The next day the diaphrams were riveted in position and the same overload placed upon the unit. At the expiration of ten hours run it was discovered that the moisture under these second conditions was less than one percent. These horizontal domes prevent any tendency to prime or foam, and drains are provided at the lowest point of each for the removal of any water of condensation.

The liberating surface of a boiler unquestionably has to be in proportion to the amount of steam to be liberated. There is some difference of opinion among boiler users as to just what constitutes liberating surface. In my opinion, it is unfair to count liberating surface in a boiler, unless it can be shown that steam is actually liberated upon the water surface under consideration.

In the horizontal type of water tube boiler, it has been customary to call the full water line in the upper drum liberating surface, but such a statement is not consistent with the facts, for the reason that steam is not liberated from all of this water surface.

These horizontal boilers have their circulation just as the vertical boiler does, and steam generated in an inclined bank of tubes rises upward to the front header and thence to the horizontal drum at the top. Sometimes the headers are connected to the drums on top by nipples and sometimes, as in the case of the plate steel header construction, by steel plate throats. In either construction, however, all of the steam generated in the boiler has to come to the surface through either the nipples or throats. The water surface immediately over these nipples or throats is the surface which is liberating

the steam. There is no steam rising from the middle of the drum and no steam rising from the rear throat, because the circulation of the water is designed to bring all of the steam up through the front header.

In the boiler under discussion, the liberating surface offered is what might be termed net. Every square inch of liberating surface is available for the separation of the steam generated from the water in the boiler. This is true because every square inch of this surface is above a tube which is delivering steam into the upper drum. In this way the highest efficiency as regards the proper liberation of steam is secured.

It has been carefully determined what size drum at the top insures a correct proportion of liberating surface. This once being assured, the same ratio of liberating surface to heating surface is maintained in all of the units, for the reason that as the unit increases the horizontal drums are simply lengthened and tubes added without increasing the height, thus maintaining the same proportion of grate surface, heating surface and liberating surface as the unit is increased. In this way the boiler can be built in 1000 horse power units just as easily as in 250 horse power units and exactly the same results obtained.

Ample opportunity is offered in this boiler for free expansion and contraction. The upper drum is held in position by a steel gallows frame, and the lower drum suspended by a series of bent tubes connecting the two drums. If unequal expansion or contraction takes place between the tubes themselves, there is sufficient spring in each tube to take care of it, on account of each tube being bent. This obviates any tendency for the tubes to work where they are expanded in the tube sheet or to develop leaks at this point. If all of the tubes expand or contract, the lower drum being a floating member simply raises or lowers to suit the conditions. The lower drum is separated from the brickwork by about one-half inch air space all around, which is filled in with mineral wool to maintain a tight setting. The main steam opening, being riveted to the top drum which in turn is held in rigid position by the gallows frame, always maintains the same position

and never brings any strains upon the steam header connected to it.

In cleaning this boiler there is no necessity of removing any hand-hole plates. Two manholes open up the boiler complete, one in the top drum and one in the bottom drum. The water driven turbine cleaner is undoubtedly so familiar to you all as to require no mention. If scale accumulates in the tubes it is readily removed by this cleaner, which is now so well perfected that it will clean any boiler tube on the market, whether bent or straight.

The tube spacing is so arranged that any defective tube can be removed without harm to any other tube. This is accomplished by spacing the tubes in pairs, leaving sufficient passage between each pair of tubes to remove a defective one.

All of the tubes are hot rolled Shelby seamless boiler tubing. The front bank of tubes are duplicates of the tubes found in the rear bank, and a complement of five bent tubes and one straight tube are all the spares required.

The surfaces in this type of boiler are all cylindrical and no stay bolts are required. There being no flat surfaces in the boiler proper, there is no opportunity for an accumulation of soot or dust. With furnace gases where the dust is very troublesome, dust collectors with clean-out doors are provided at the bottom of front bank and bottom of rear bank of tubes below the bottom drum. For blast furnace gases and waste heat propositions the construction of the boiler is varied, the gases being passed only twice; upward through the front bank of tubes and downward through the rear bank.

The principles involved in this boiler are not new, with the possible exception of the horizontal steam domes. The boiler is rather a combination in a new design of well demonstrated principles. The bent tube construction, particularly since the advent of the turbine cleaner, perhaps has more followers at the present time than the straight tube. Certainly it has been thoroughly demonstrated as applicable to water tube boiler construction.

The dutch oven and flame travel as applied to this new boiler are found in many of our most reliable installations.

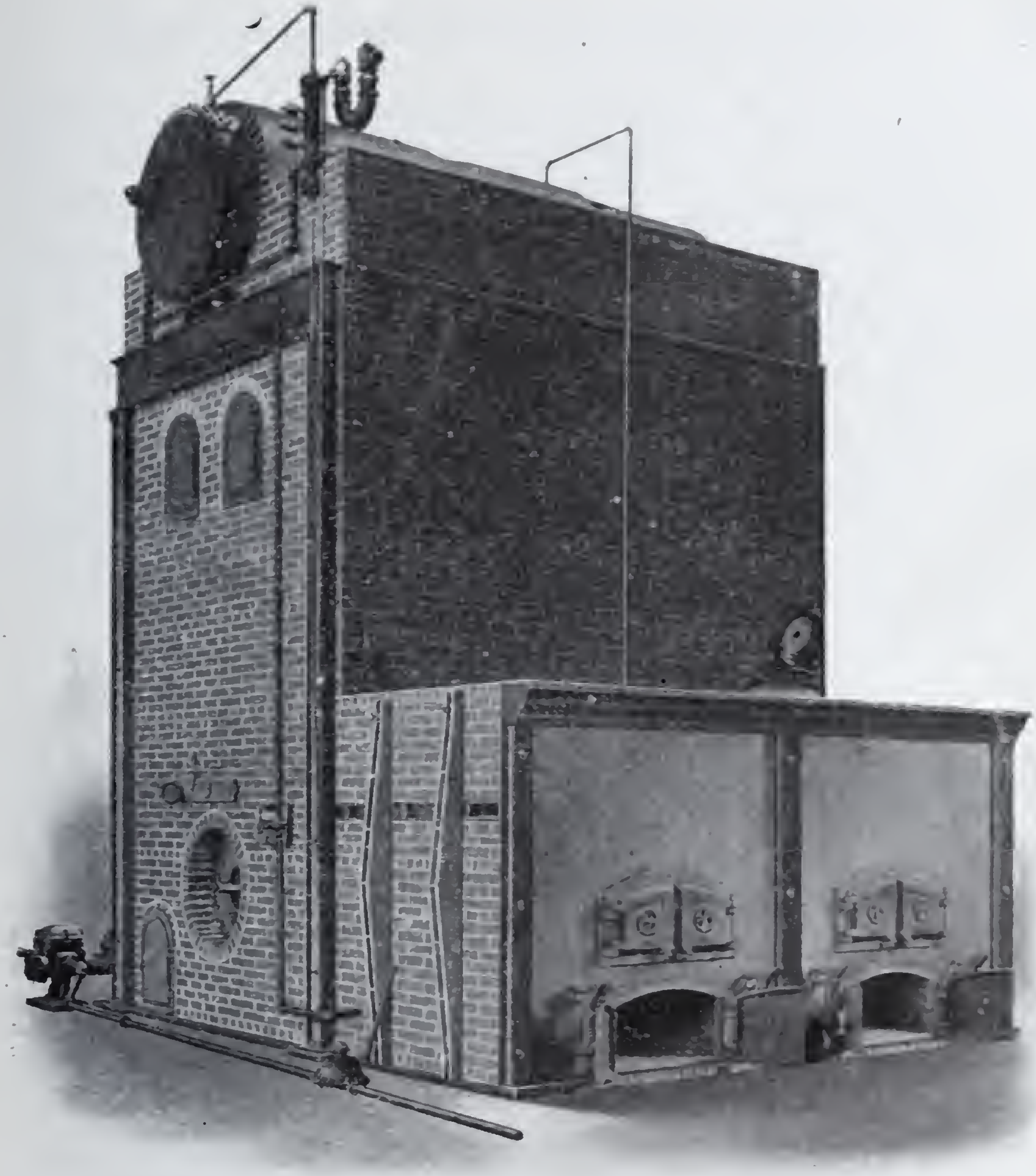

Fig. 3

So in this way it is possible to go through point by point each detail in design and construction and in each step it is apparent that rather than being a new invention or departure in any way from the old established customs, it is on the contrary simply an embodiment or combination of good features taken from a score of different designs.

The boiler has been carefully tested and shows excellent efficiency and high overload capacity. On account of its simple construction it is possible to build the boiler throughout of the very best material and with the best workmanship and at the same time maintain a reasonable selling price.

The boiler is usually set as shown in Fig. 3, but it may be erected with an air tight steel casing, if preferred, instead of the brick setting. Where the steel casing construction is used, the interior surface is lined with 9 in. headers of fire-brick. This steel casing eliminates any possibility of cracking the brick setting and the resulting admission of cold air, as well as improving the appearance of the boiler house. The fire-bricks, which are placed as 9 in. headers, are not in a perfectly horizontal position. The bottom course of brick is started on an angle of about six degrees, and all of the lining is put in with the bricks on this inclination. This gives an air space between the fire-brick and steel casing.

DISCUSSION

Mr. Richard Hirsch: There is one question that occurs to me in regard to the deposit in the tubes. How does the formation of scale in vertical tubes compare with that in tubes more nearly horizontal?

The Author: The deposit in vertical tubes will of course not have the opportunity to lodge or gravitate to the low side of the tube. The force of gravity will carry it downward and into the drum at the bottom. We often cut tubes from horizontal boilers through with a saw, invariably finding that about two-thirds of the scale is on the under side of the tube and a smaller proportion, not over one-third, on the upper side.

Mr. L. C. Moore: I would like to inquire the cost of this type of boiler as compared with the same power of other boilers.

The Author: We have only built 75 000 h. p. of the boilers, and that is not enough to know exactly what the cost will be; but it is safe to say that the boilers can be built for at least one dollar a horse power cheaper. That is not from anything I know from the cost sheet, but simply judging as you would judge of it. It is a very simple boiler to build, the drums are of simple construction, no stay bolts are re-

quired, and the tubes practically do not cost any more bent than straight.

Mr. H. S. Prichard: Did I understand you to say that the tubes were kept the same size in all the boilers?

The Author: The length of the six different tubes used is kept the same in all of the standard boilers. But when the boiler is modified for the two-pass design, that is for waste heat gases, we use a 4 in. tube of greater length. But, in turn, that is maintained for the two-pass design, so they are all the same.

Mr. J. W. Todd: I was wondering whether there is any trouble from having steam liberated at the same point where the water is going down in the back tubes in the upper drum. At a single point toward the back of the drum you have the steam being liberated on one side and the water going down in the opposite direction.

The Author: This is a point that would be open to discussion. One man's opinion is just about as good as another's as to just what takes place there. As the rising steam comes up the front bank of tubes it liberates. The idea is, if it works as I think it does, that after the liberation of the steam the water goes across the upper drum and down the rear tubes. Whether or not the circulation is so strong as to cause water still charged with steam to go down the rear bank is something that I could not say positively. But at any rate it has been determined pretty carefully that there is not sufficient carried down the rear tubes, if there is any, to have any bad results in the operation of the boiler.

Mr. W. W. Macfarren: There is one point that occurs to me. It seems to me that in the two-pass boiler the difference in expansion between the outer and inner tubes would be neutralized to a great extent by the spring in the bent tubes. But in the three-pass boiler, where there are both straight and bent tubes used, there would be somewhat of a fight between the straight and the bent tubes as to which would take the brunt of it.

DISCUSSION OF PAPERS

Members of the Society and also other readers of the Proceedings are urged to send to the Secretary written discussion of papers after publication, which will be printed in succeeding issues of the Proceedings. We believe that much valuable information may be presented in this way, and it is hoped that this feature of written discussion may be made a prominent one in the Proceedings.

DEFORMED BARS VS. ROUND RODS ANCHORED FOR REINFORCED CONCRETE

By J. H. Toupet*

Reinforced concrete is no longer a new material but has entered the engineering field to stay. With its application to all kinds of structures many systems have been invented, some of which are based upon logical principles, reliable experiments and a few years of practical results; while others are poor imitations of the pure gems and will soon drop out of sight when engineers, architects and contractors become better acquainted with their respective values.

The various systems used differ not only in their general design but more especially in the shapes and qualities of the tension members used. It is not our aim to describe these systems and the qualities of the different grades of steel used, but to confine ourselves to the advantages and disadvantages of the shapes used which are of two general classes, *plain* and *deformed bars.*

The simplest shape and the most easily gotten anywhere is no doubt the round rod. This shape has many distinct advantages, among them that of giving the greatest sectional area under the smallest volume; it is easily bent, is symmetrical about its center of gravity, has no sharp edges and can be handled rapidly without injury to the hands which feature is not to be overlooked from a contractor's standpoint.

Round rods were first used in reinforced concrete structures in Europe where they are still used almost exclusively, while the tendency seems to be towards deformed bars in the United States. The reason for this is on account of the different ways and means engineers employ to get at the same result. In the United States materials are cheap and labor is expensive so that usually, as far as possible, the cheaper grades of labor are used in building work. In Europe exactly opposite conditions prevail; materials are expensive and labor

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* Chief Engineer, Electric Welding Co., McKees Rocks, Pa.

is cheap so that contractors can well afford to use a higher class of labor. Both ways harmonize perfectly with the actual conditions and both of them are to be recommended since they result in either case in a saving on the total cost of the structure.

The class of labor employed in Europe on this work, though paid only 60c to $1.00 per day as many of you probably know, is to be compared with our skilled mechanics whose wages are from $3.00 to $4.00 per day. You will now understand that it is possible to rely upon European laborers with far more certainty than can be done with the laborers employed in this country since their grade is altogether different. For this reason European engineers have usually used the plain round rods in reinforced concrete work, which have always proven satisfactory so far as I know. Some, however, have bent the ends in such ways as to secure a better anchorage, as they were afraid of defective work. In the United States it is altogether different and we prefer to spend a little more money on materials, since they are cheaper, and also to use such a system that will leave but little to the initiative of the laborers and so insure ourselves against defective work. This, I repeat, is entirely justified on account of the widely different conditions.

It would, no doubt, be poor practice to use plain round rods without any kind of anchorage in this work unless the supervision was so perfect as to avoid any chances for doubtful work.

Inventors have come forward with numerous devices aiming to overcome such chances and the deformed bars were placed on the market by enterprising business people who saw a chance to make money, while others thought their devices to be technically perfect, often through lack of the special knowledge that reinforced concrete involves.

By deformed bars I mean bars with any kind of kinks, bumps, recesses, holes, corners, twists, notches, etc. I think that most of you gentlemen who are engaged in the building line have been misled as to the value and effectiveness of these

so-called deformed bars, through error, since so many of the inventors knew so little about concrete that they are excusable for their products.

All of you know that in the design of reinforced concrete members, the concrete is relied upon to take all the compressive stresses while the steel takes the tensile stresses. These tensile stresses are transmitted to the steel bars through the medium of the concrete only and this is possible on account of the physical property known as adhesion or bond between the concrete and the steel. It is, of course, well to increase this bond to the greatest possible unit figure in order to get the best results and numerous devices have been patented which aim to a greater safety.

Some kind of anchorage, mechanically obtained, is necessary in order to secure safe results, but we should know exactly what we are doing, and what additional stresses are impossed upon the concrete by the use of these devices.

First let us see how deformed bars act when embedded in concrete. The adhesion of the concrete to the steel is mostly due to the contraction of the concrete while setting and when a tensile stress is exerted upon the bar it is resisted by two forces known as tangential and normal adhesion as shown by Mr. R. Feret* in his experimental researches recently published.

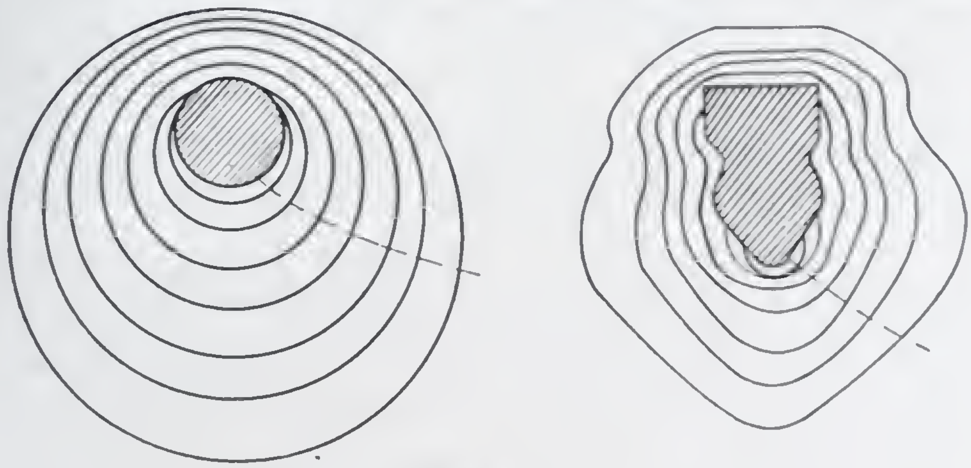

Fig. 1.

Now in a reinforced concrete beam these conditions of transmission of stress are reversed and the concrete must transmit the tensile stresses to the steel rods but the same forces still are there to produce the necessary grip or bond. Besides

*Étude Expérimentale Du Ciment Armé.

these, other internal stresses known as secondary stresses also occur, such as the propagation of the normal and tangential adhesion through the strata of the concrete, as shown in Fig. 1, in the same way that electrical waves and magnetic forces are propagated around a pole. This also has been studied by Feret and we will not go into more detail now, but wish that all would bear these points in mind as they are most important.

The more deformed the bars, the more uncertain the secondary stresses, since the propagation has a tendency to follow the broken lines, as shown in Fig. 1, and the equation of these stresses in the case of deformed bars seems to be a mathematical impossibility, though Mr. Feret has made a study of the stresses in the case of round rods.

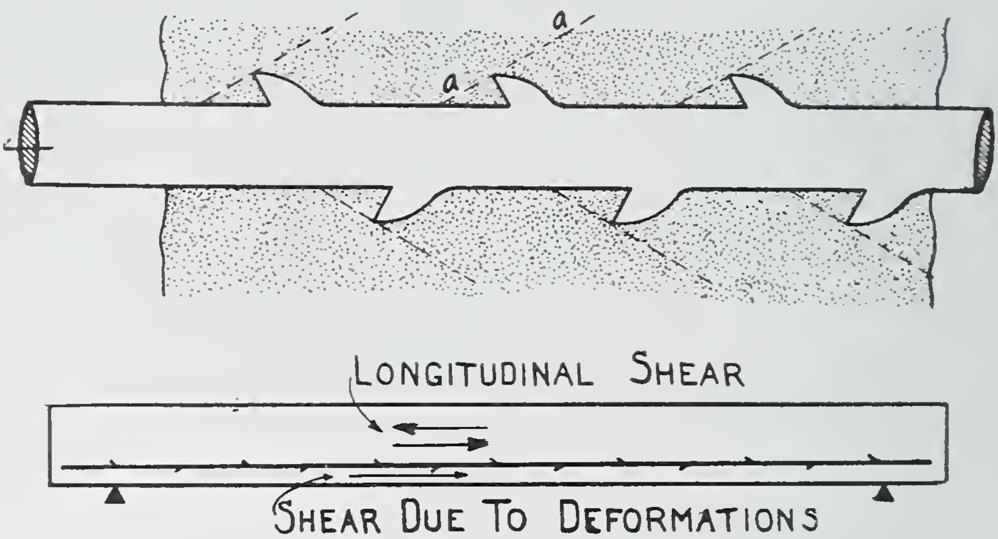

Fig. 2

The mechanical bond obtained with deformed bars is due to the tendency to resist slipping through the concrete on account of the deformations. A greater resistance to slippage than with round rods is of course secured but at the same time, and as a natural consequence, a greater longitudinal shear obtains. This additional stress which results from the use of deformed bars constitutes the main obection to their use. This stress may vary with the shape of the bar; but it always occurs and is a minimum for the smoothest surface, that is for the round rod.

To show you a little more clearly what I mean, suppose that a bar, as shown in Fig. 2, is embedded in concrete. When

a tensile strain is exerted upon the concrete to be transmitted to the steel rod the concrete will naturally have a tendency to shear through the planes *aa*, possibly not exactly those indicated, but through similiar planes more or less inclined. This shearing strain is repeated at each and every deformation, varies at every point of it and also at every point of the bar in proportion to the tensile stress to be transmitted. The summation of all these shears constitutes a very indefinite strain which is a part of the additional longitudinal shear mentioned before. This stress is a direct result of the deformations. It is in fact a direct shear along the longitudinal axis of the beam. Another increase in the longitudinal shear is due to the greater bond which is secured with a deformed bar when properly embedded.

The total longitudinal shear due to pure adhesion, and to deformations, if any, must be taken by the concrete web since this stress is distributed through the concrete and the necessity of a web thick enough to resist it, is at once apparent. In other words it shows that an ample spacing between the rods should be allowed in proportion to their cross sectional area and also to the additional longitudinal shear they may develop on account of the deformations.

It means that with an increase in the bond a proportional increase in the thickness of the web should be allowed, which is never done. I might say that the contrary is true and that quite a number of people using deformed bars reduce the surrounding concrete to such a thickness that it becomes very dangerous.

If designers were willing to take into account the additional longitudinal shear consequent upon the use of deformed bars, which they ought to do, it would be very difficult to make a theoretically correct design since these stresses are unknown and a guess can only be ventured as to their value. However, it might be well to increase the thickness of the web in proportion to the bond given by the deformed bar, taking as a basis the plain round rod.

The question now arises: How much good do we get out

of the use of deformed bars if we do not know the exact value of the additional stresses consequent upon their use? No engineer or contractor would, as far as I know, take a chance in other lines of construction, but they do in concrete work, for the very reason that additional stresses creep in as explained before. I understand that it would be difficult to mathematically demonstrate the extent of such stresses. All that is necessary to be thoroughly convinced of their existence is to follow a logical line of reasoning and study the experiments made by reliable authorities who are not paid for securing special results.

I would also like to call your attention to the fact that some deformed bars may produce a torsional moment in the concrete while some others are so wide and so placed that a decided breaking plane is formed through the concrete, especially in the webs of beams heavily reinforced.

To summarize the situation, deformations always produce additional stresses of indefinite value which more than offset the greater bond obtained. These additional stresses are very dangerous especially with green concrete; when the centers are struck the concrete is never perfectly set and great care should be taken that no undue strains come upon it, the stresses due to bending under the dead weight of the structure being the only ones that should be permitted and these should be reduced to a minimum.

When diagonal shear members are made of deformed bars bent up, it is needless to say that they are of little value since they cannot be developed to a stress anywhere near that computed. These bars require a positive end anchorage to be effective as do round rods or plain bars of any shape, since their stress must be entirely developed at the point where they cross the neutral axis of the beam. Deformed bars also give a chance for air holes, a very objectionable feature which many of us have encountered on numerous occasions.

When reinforced concrete was still in its infancy, a number of devices were used as anchorages for plain round rods, the most common being the bending of both ends of the rods in a

hook shape, which is shown in Fig. 3 together with some other forms of anchorage. The rods were awkward to place in position and the distribution of the stresses around the anchorage technically imperfect. Hennebique, one of the pioneers in reinforced concrete construction, used rods with both ends split in a fish tail like manner and his followers are still doing it. This process is very expensive and would be prohibitive in the United States on account of the amount of labor involved.

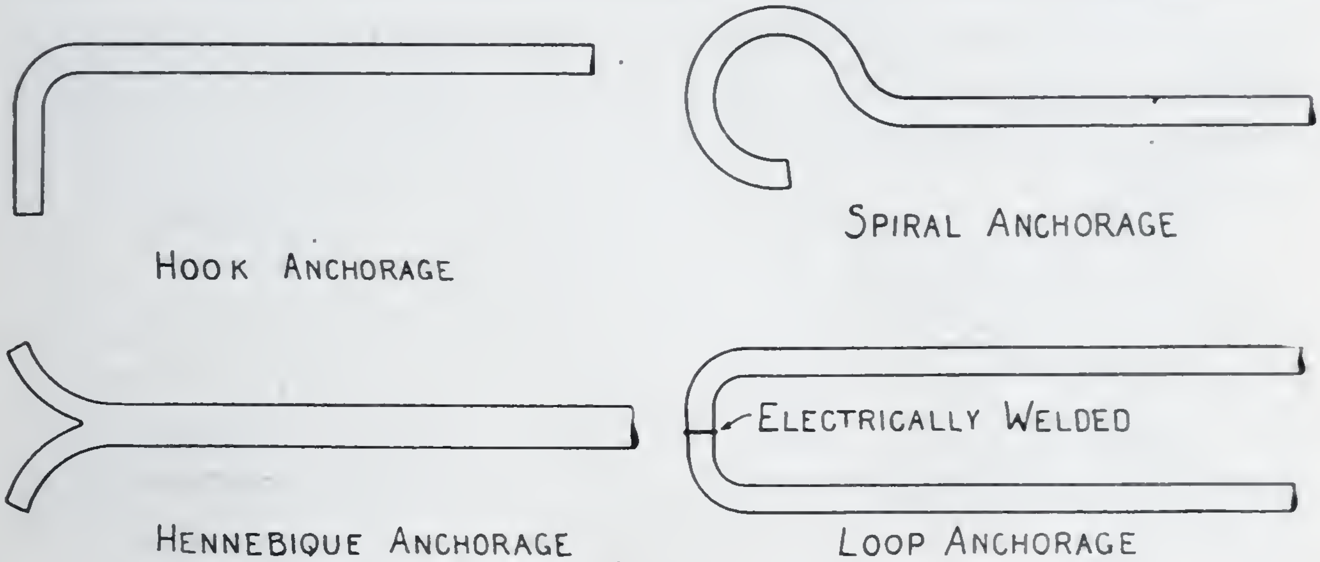

Fig. 3.

Another way of anchoring round rods was suggested a few years ago in the form of a spiral anchorage which is theoretically perfect as far as distribution of stress goes. The compression around the coil of rod, if not equal at all points, is very much better distributed than in any other form of anchorage and for this reason it would seem to be the best were it not for its great practical drawbacks. It is very expensive and it is nearly impossible to realize when applied to rods larger than 3-4 in. diameter; and the connections of concrete members, for instance at a column, are so full of steel that it becomes a practical impossibility to place the concrete with any degree of certainty.

The next end anchorage, which appeals to me as being the best, although it is not theoretically as perfect as the spiral, is the electrically welded loop, which is made by bending both ends of the rod at right angles and welding them together. It is practically a perfect end anchorage since the rods cannot slip in the concrete under any circumstances, and the stresses con-

sequent upon this method of anchoring are merely compressive and not longitudinal shear as in the case of deformed bars.

The bends are made with a sufficient radius so that the rods are not weakened and the welds have a practical strength of 9-10 that of the rods as proven by numerous tests. It is to be noted that these welds are located at points where the stresses are nil, or very small, so that there is no chance left for a dangerous structure. This loop anchorage, shown in Fig. 3, requires no explanation and I believe that it will appeal to all as being a thoroughly reliable anchorage. The cost is not prohibitive and the result is a very stiff unit for slab, beams, or girders.

The anchorage of tension members should always be made at their ends and not along their entire length as in the case of deformed bars, or of plain rods without bends at ends, for the following reason: The concrete is usually in greater tension near the center and at the bottom of a beam than near the supports; for instance, we all know that for a simple supported beam there are no tensile bending strains at the supports and that such strains are maximum at the center of the span, while in more or less continuous beams the tensile strains in the bottom of the beam, are nil at some points between the supports and the center of the span, which points are of variable location according to the more or less continuity of the member considered. The stresses are also reversed at the supports in the case of continuous members. The amount of steel required in simple and continuous beams is shown in Fig. 4, in a diagramatical way, which amount varies in a direct ratio to the absolute value of the bending moment. The beams are supposed to be uniformly loaded.

Of course it would be very poor design and bad practice to stop the rods back of the supports in continuous girders, or slabs, since other stresses, such as vertical shear at the supports or tension due to a particular loading, may occur just where there would be no reinforcement to take care of it. A strong connection is always desirable at columns even at the expense of a little more steel. It is good policy, however, and effects

great saving to have the amount of reinforcement vary within reasonable limits, from the supports towards the center of the span.

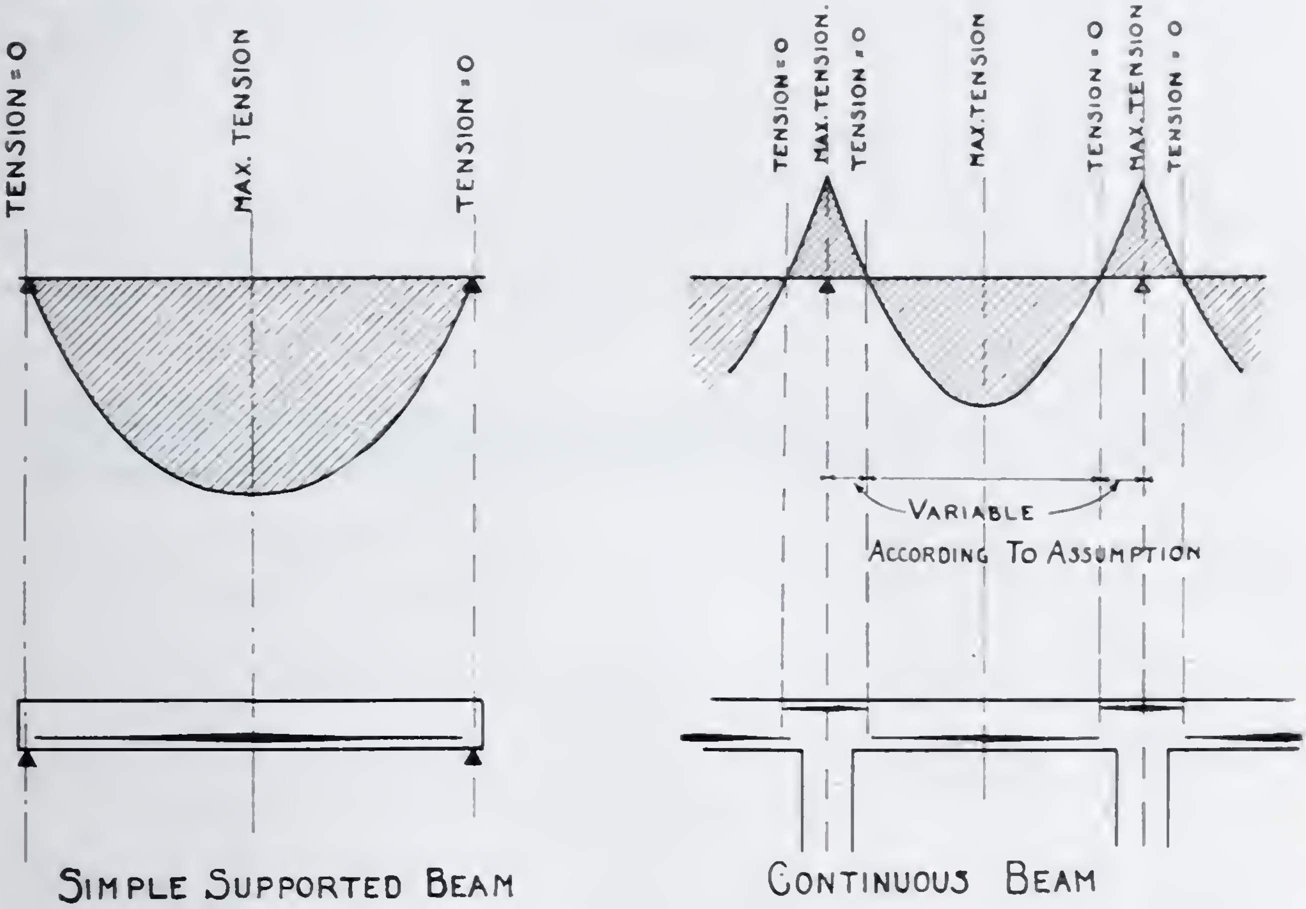

DIAGRAM SHOWING THEORETICAL AMOUNT OF STEEL REQUIRED IN TENSION

Fig. 4.

In the simple supported beam, shown in Fig. 4, the anchorage is made in what might be called an inert body since there are no tensile stresses in the concrete at these points and the anchorage of the rods is thus secured with a minimum stress upon the concrete. In the case of continuous members the end anchorage is made in the compression side of the beam and its value is increased since the compression acts upon the rod as a superload tending to increase the effectiveness of the anchorage. This loop anchorage has never failed and practical tests have shown its great reliability.

Mr. R. A. Cummings has developed a system of reinforcement along the lines outlined for the loop anchorage, the principal features of which are: A positive end anchorage secured by the electrically welded loop, a shop made reinforcement avoiding misplacing of the steel, and a correct and econom-

ical distribution of the steel through the use of the loop truss shown in Fig. 5. Whenever there is too little room for the

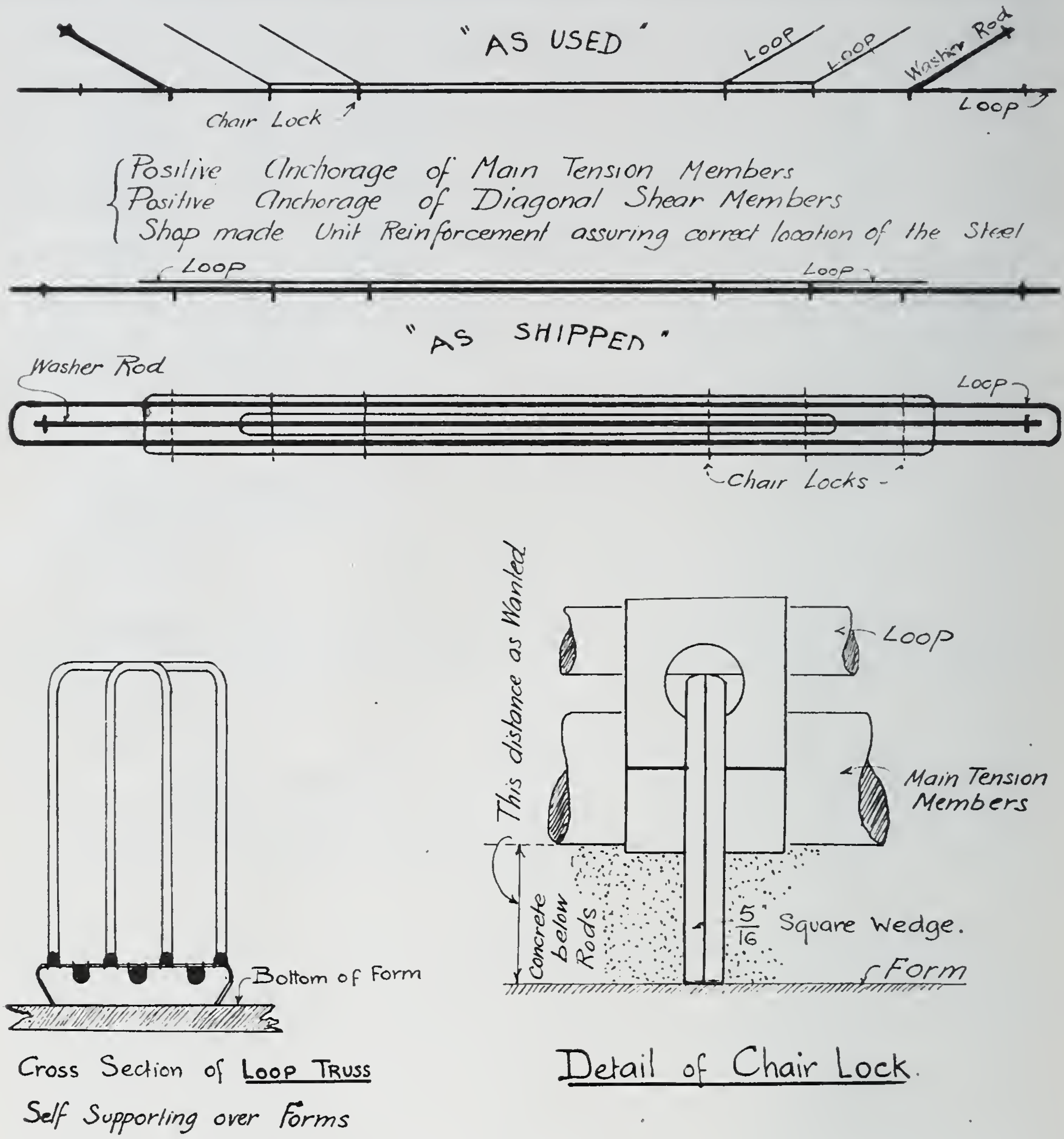

Fig. 5.

loop, a washer is welded at the ends of the rod forming a positive anchorage which absolutely prevents slipping of the rods in the concrete.

It is to be noted that the beam is of varying cross sectional area and that is a very economical design. The diagonal shear members are part of the main tension members which is very desirable and they are also securely anchored at the ends by means of the loop. These diagonal shear members are, as previously pointed out, of little use if not securely anchored at the

ends. In this loop truss the diagonal members can be developed to their ultimate strength without slipping, and I do not know of any other design as safe as this one. The loop truss is a shop made unit, it is shipped flat, is easily placed in the forms and is self supporting over the forms.

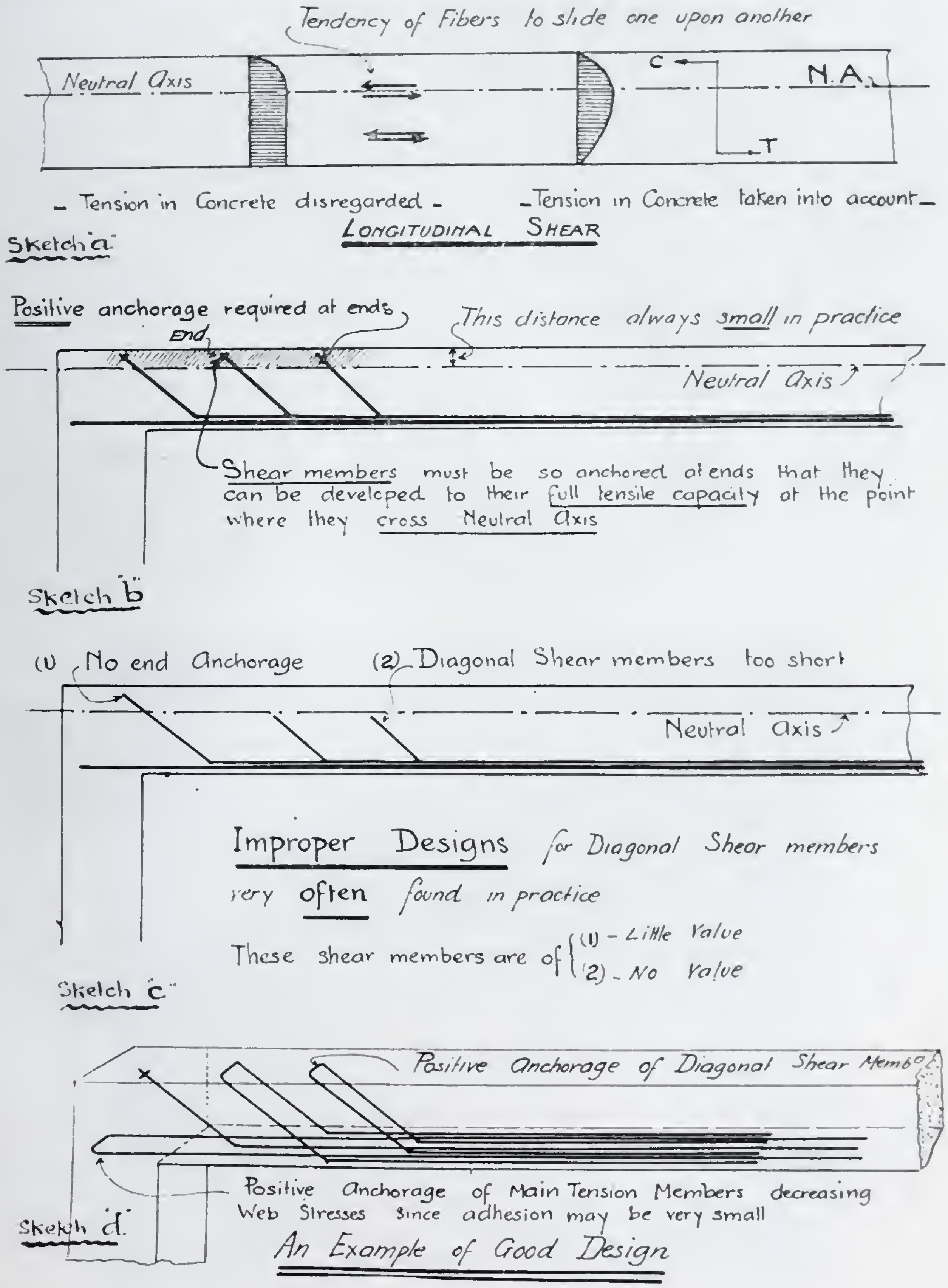

Fig. 6.

In sketch *a*, Fig. 6, is shown diagramatically the value of the longitudinal shear in a beam when the tension in the concrete is either neglected or taken into account.

The distance from the top fiber to the neutral axis being always very small, as shown in sketch *b*, Fig. 6, usually about 2-10 of the total depth of the beam, and as the diagonal tension members reach in practice to but within 2 in. from the top of the beam, it is evident that a positive end anchorage of the ends of the diagonal shear members is absolutely required since these must be developed to their full strength at the neutral axis.

Sketch *c*, Fig. 6, shows some improper designs very often found in practice. Diagonal tension members which are a part of the main tension members, are a required feature, but they must be anchored at the upper end and are of little value if not anchored, and of no value at all if too short.

Sketch *d*, Fig. 6, shows an example of a correct design: The loop truss with the diagonal tension members an intregal part of the main tension members, and thoroughly anchored

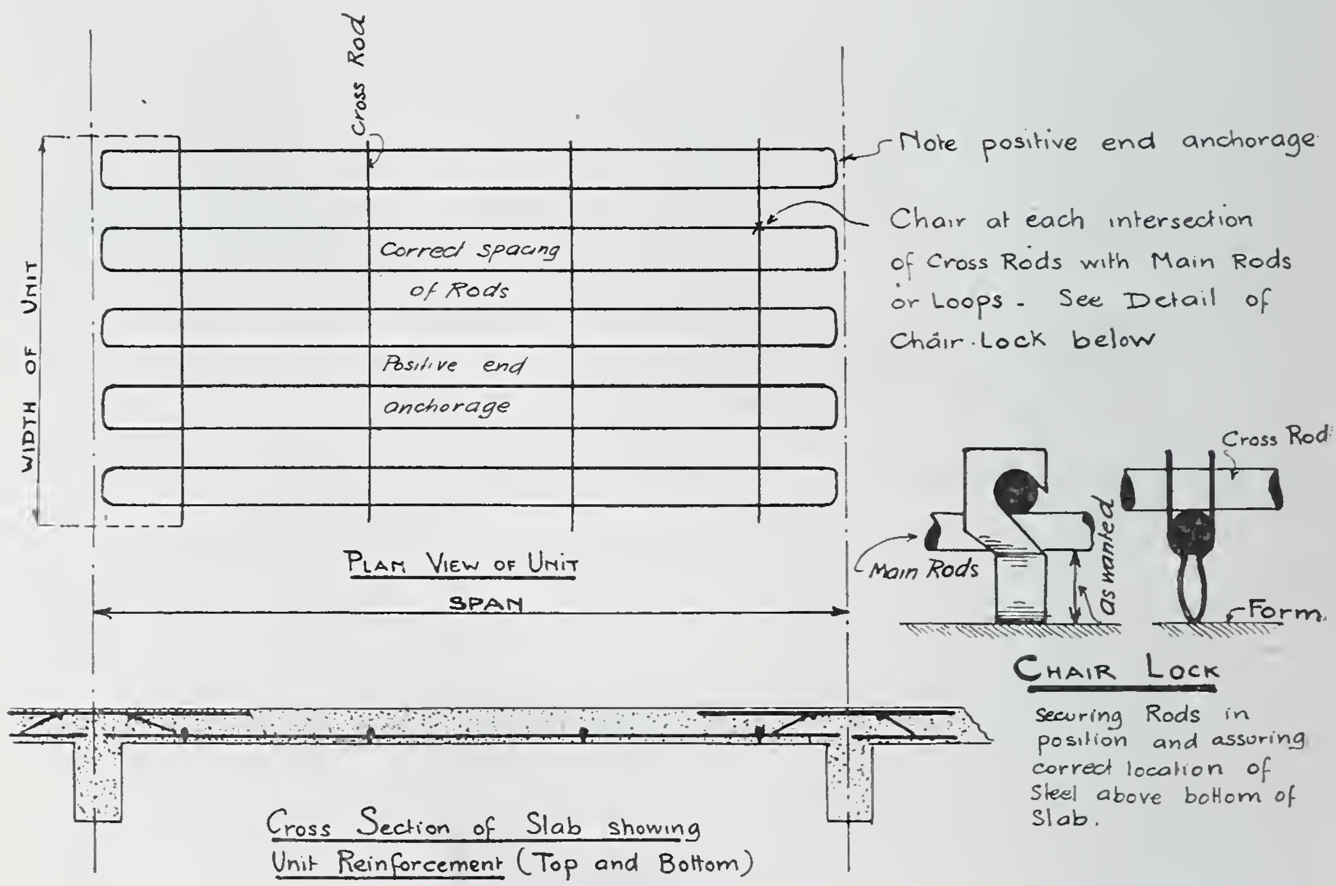

Fig. 7.

at the upper ends by means of a loop or an electrically welded washer. There is no possible slipping of the rods through the concrete.

It is needless to say that round rods can be combined in a thousand or more different ways to thoroughly correspond with the engineer's calculations. It is our practice to design a beam for the particular loading it has to carry as the shear members are variable in most every case. The loop anchorage, as shown in Fig. 7, is used in making units for slab reinforcement and has proven very satisfactory in every case.

The question may be asked why so many deformed bars are sold and why quite a few are a commercial success. This can be answered in a very few words: The American people take the lead for their business ability, their ceaseless energy and their admirable methods of advertising, which latter often makes a success of an undesirable product. Contractors are often willing to consider the cheapest as the best no matter what the final results may be, and this is the real explanation for the success of a few products which, if they prove to be a good financial result, are a very poor engineering success.

Fig. 8.

Figures 8 to 10, taken from photographs of tests made at the Lehigh Valley Testing Laboratory at Allentown, illustrate very plainly what has been said about the necessity for end anchorage. Fig. 8 shows that the diagonal shear members

Fig. 9.

Fig. 10.

slipped about 2 in. in the concrete indicating that they were of no value whatever. Fig. 9 shows that the hook anchorage was effective, but that it had a tendency to straighten out under the strain. Fig. 10 shows the loop anchorage, indicating that this method is perfectly reliable. It will be noted there was no crushing of the concrete under the loop and that no slipping occurred even at the breaking load.

I am indebted to Mr. R. A. Cummings for these photographs, which I think are of real value in illustrating the points brought out in this discussion.

CORRESPONDENCE

Mr. Edward Godfrey*: There are some features of reinforced concrete design as carried out in the large majority of structures as advocated in the majority of works on the subject that will not stand the test of rational analysis or even common sense. These features concern most directly the deformed bar.

In the minds of many designers and writers the deformed bar seems to be invested with some magic power that defies the ordinary laws that govern design in materials other than reinforced concrete.

A reinforced concrete retaining wall will be designed and built with a front curtain wall and a horizontal slab joined at intervals by counterforts containing a mass of vertical and horizontal rods and writers will sagely describe their counterfort as a beam. A very little reasoning will show that the counterfort is not a beam in any sense, and that this mass of rods is about as illogically and extravagantly placed as they could be. The tendency of the vertical curtain wall and the horizontal slab is to pull away from each other, The only logical way that these rods can be used is as ties, anchored respectively into the vertical curtain wall and the horizontal slab. The concrete of the counterfort is merely protection for the rods. The weak section of the counterfort, as ordinarily

* Structural Engineer, R. W. Hunt & Co., Pittsburgh.

designed, is at the back of the curtain wall or just above the slab. Besides rupturing the concrete tension, a thing that may be done by a shrinkage crack before the wall is finished, the mere pulling out of a few inches of rods is enough to cause failure. The most ardent advocate of deformed bars would not assert that a few inches of anchorage is sufficient to develop the full strength of the bar. Plain bars with nuts and washers, or attached to the steel reinforcement of the curtain wall and slab by thread and nut are of enormously greater value than these deformed bars. Deformed bars do not admit of effectual end anchorage, and they have absolutely no advantage in a case of this sort. The greater part of the deformed steel in a counterfort designed in this bungling way is thrown away.

A hook on the end of a bar is no more an efficient end anchorage than is a hoop on the end of a tension member of a steel bridge. It is in fact less so in the proportion of the strength of a steel pin to one of concrete.

Another gross error in reinforced concrete concerns the spacing of bars in the bottom of a beam where there is no end anchorage on the bars. Many designers and writers pay little, or no attention, to the needs of a properly designed beam. They use deformed bars and imagine that the beam will be first class, because some beams with deformed bars have stood large test loads. Deformed bars will take a better hold in the concrete, they reason, and this is as far as their reasoning goes. If these deformed bars take a better hold in the concrete, more concrete is required to grip them and to take the other stresses of the beam, and further, if the concrete is used in sufficient amounts and properly placed, it will grip a plain bar with all of the hold that is needed. This is a point in which the logic of the deformed bar designer is fatally weak. He is content to use enough concrete for fire protection and to keep the rods from touching each other. Several banks of rods are sometimes used, and the width of beam is sometimes about what it should be for one of these banks.

The *T*-beam, in its common analysis, is covered with a fabric of figures and bewildering formulas with 25 or 30 con-

stants and variables to be estimated and guessed at, and the simple fact that this same beam is too narrow to carry its own shear is totally lost sight of in the minds of many who follow these mathematical magicians. If the *T*-beam were wide enough to take the shear incident to the stress of the rods, it would be found ample in width to take the compression without counting in any of the floor slab. Deformed bars are here again the wand by which the magician turns a material, (concrete), weaker in both compression and shear and vastly less tough, into one that will carry theoretical loads which would shatter any wooden construction. This is not an idle figure. The writer tested some *T*-beam construction that would not be tolerated for an instant in the same dimensions in wood and found dangerous conditions and incipient failure under the designer's "safe" load. The designer's "theoretical" breaking load was three times the load of the test.

T-beams can be made, and a properly reinforced concrete slab could be made use of, if the reinforcing rods were curved up and anchored over the supports, as then the stem of the *T* is relieved of shear. The concrete merely rests on the rod as a saddle and the compression is imparted to the beam through the anchorage at ends of rod.

Someone will point to the stirrups used in the regulation reinforced concrete beam and ask why these cannot take the shear. The writer has never seen any approach to a rational analysis showing how stirrups or so-called shear members can take shear. That a steel rod in concrete can take any actual shear (as shear in the steel) at any unit stress that would justify its use is quite absurd. Imagine a pair of shears made with concrete blades cutting a steel rod. If these shear members could take a little shear, where do they get it? How could a loose bar looped around a rod take any part of the tension in that rod? Would a bridge designer think of merely wrapping the diagonals of a truss around the chords? Suppose a shear member does get some shear through the medium of the concrete or by attachment to the bar, where does it part with that shear? For the carrying of shear through the web is

merely incidental to its being imparted to the compression flange of the beam. Does the "shear bar" give off that shear, as an electric current might be given off, at its extreme upper end, where it floats in the concrete?

Or suppose the shear members are inclined and their stress is tension. How do they part with that tension? Even the worst case of deformity in a bar demands some length for anchorage. Deduct this length from the shear bar, and its useful portion is a small fraction of its length, and this is located at the bottom of the beam where it is of very little use. End anchorage of shear bars would only aggravate the case by complicating it and adding more impediments to the placing of concrete.

End anchorage of the main reinforcing bar of a beam is a perfectly rational feature of design, and if some of the bars are curved up at ends and anchored over the supports, no shear members are needed. The curving up of reinforcing bars at or near the ends of span and leaving them with floating ends is bad and extremely illogical.

Tests made at the University of Illinois Experiment Station, and described in their Bulletin No. 29, on beams having plain rods with end anchorage showed excellent results. Nearly all of the cracks were confined to the middle third of the beam, and the beams failed either by tension of the steel or crushing of the concrete. These are ideal failures and the simplest of all to provide against. When a beam fails by shear or pulling the short end of the rod out, failure is sudden and disastrous. The other failure may mean merely the sagging of the beam.

In the same Bulletin beams with stirrups and rods not anchored at the ends were generally cracked near the supports, and many failed by shear and pulling out of the rods. The Bulletin amply demonstrates and reiterates the fact that shear bars are practically useless until failure starts, when of course they help to hold the beam together and prolong final collapse. End anchorage of plain bars is shown by this Bulletin to be excellent.

DISCUSSION

The Author: I agree with most of Mr. Godfrey's remarks, but to be fair, I must say something in defense of the loose stirrups. Mr. Godfrey says that loose stirrups cannot take shear. Of course I, myself, think that diagonal tension members made as part of the main tension rods and properly anchored at the ends is the right construction; but loose stirrups will, to a certain extent, prevent the sliding of the concrete fibers one upon the other, and thus take some shear.

Diagonal tension members, of the description given above, thoroughly connect the tension and compression sides and are most advantageous in that way. The inclination of these shear members is a matter of experience and there is no theory on it. An inclination of 30 deg. above the horizontal for continuous beams, and of 45 deg. above the horizontal for simple supported beams, seems to give the best results. This has been proven experimentally.

There are, in fact, three kinds of shears: Direct shear; longitudinal shear through the web of the beam, due to the tendency of the concrete fibers to slide upon one another; and a longitudinal shear around the periphery of the rods. These three shears are tied together in a certain relation which depends upon numerous factors, among them the shape of the rod, so far as the third is concerned.

Most people admit that the end shear is equal to the total longitudinal shear in one half of the beam. The diagonal tension members will take care of this through direct tension, the tension being smaller per unit of area with their greater inclination above the horizontal.

Loose stirrups will resist longitudinal shear to a certain extent on account of their resistance to being sheared off in a horizontal plane, when the fibers of the concrete tend to slide upon one another. The loose stirrups do not connect the tension side to the compression side in any material way and for this reason I do not think their use necessary when the shear is properly cared for by diagonal tension members.

I do not agree with Mr. Godfrey when he says that if a *T*-beam were designed with a web thick enough to take the shear, it would not require a *T*-section to take the compression. I do not think that this statement is correct although a number of people figure on a width of flange which is altogether out of reason.

The *T* action is one of the decided advantages of reinforced concrete beams, but these *T* sections must be designed very carefully on account of shear in the web of the beam and proper reinforcement must connect the slab to the web which is the case when diagonal shear members are thoroughly anchored at the ends.

However, I think Mr. Godfrey's idea is just right in this way: The web of beams should always be of ample thickness, first to resist shear and second to enable a proper spacing of the rods to be made with plenty of room for the concrete to get in between the rods and thoroughly surround them. Common sense must be used in all designs, especially in reinforced concrete work.

A MEMBER: Are we to gather from your remarks that you consider plain rods with bent anchorages cheaper than deformed bars, weight for weight?

THE AUTHOR: I do not mean so; I mean in the final result. Round rods or other plain bars properly anchored will cost probably a little more than deformed bars when the cost of providing the anchorage is added to the nominal cost of the steel rods. Weight for weight, the round rods with the proper anchorage will win without any doubt, if the strength of the structure is taken into consideration.

The only way to make as good a structure with deformed bars as with rods, is to provide the deformed bars with one of the end anchorages mentioned. In that case there is evidently no use for deformation and the deformed bars will then cost more, weight for weight, for the same efficiency since their cost is at least $2 to $3 more per ton.

A MEMBER: No mention has been made regarding the

hardness of the steel used for reinforcement. Is there any preference?

THE AUTHOR: I did not intend to touch the subject of the qualities of the steel used in reinforced concrete work. I think that what is known as a medium open hearth steel is preferable to others, as it is hard enough without being brittle. It is easily bent cold without cracking which is a very decided advantage since there are no structures built without bent rods. The high carbon steel is, I think, a dangerous material as it is usually very brittle. Less steel is required and an economy of material is realized; but it is poor economy if we are to take any chances on the strength of the structure. Another big objection to its use when in shape of deformed bars is the greater shear around the periphery of the bar since they are smaller or less in number than with mild steel. However, I think that comparatively little high carbon steel is used for reinforcement.

A MEMBER: What would you consider as a high carbon steel?

THE AUTHOR: Over .40 I would consider high carbon steel and I think it is well to use steel of .25 to .30 carbon only. Every foreman on a job can detect high carbon steel by bending, and will also tell you that he has broken many rods that way.

Of course high carbon steel, if used at all, should always be bent hot. But I guess it seems easier to do it cold and unless inspectors are there all the time, the contractor, or his superintendent, very often forgets to have the rods heated.

Some people allow 20 000 lb. per sq. in. on high carbon steel. I think this too high and that a medium open hearth steel is more reliable at 20 000 lb. per sq. in. than high carbon steel.

MR. R. B. WOODWORTH: I thoroughly agree with the author and I certainly appreciate the privilege of hearing the paper tonight. It has been most excellent. I would like to ask one question, and that is, to what extent in reinforced concrete work are the bars bent beyond 90 deg.?

The Author: The hook shape is used as an end anchorage by many engineers and contractors who advocate the use of plain rods. It is, I think, a pretty good anchorage and, in many cases, is used preferably to better ones on account of patents. People who use their own judgment and make their own designs have to be careful not to infringe upon patented designs, and the difficulty hinges upon this point, because quite a number of devices have been patented which should not have been, since they probably were used at all times and are not original ideas.

I think that most contractors using the hook anchorage make it too short, some making a hook possibly four inches long on a one inch rod to save material and trouble in placing. I think that the length of the hook should be about fifteen diameters of the rod. Better have it too long than too short and the expense is very slight in the long run.

A threaded rod with nut and washer makes a good reliable anchorage but it is very expensive and one cannot think of using it except in a very few cases.

Mr. J. J. Shuman*: I think the author is somewhat misinformed when he says there is a very little high carbon steel going into reinforced concrete. I am afraid there is a good deal of it going in, and I do not think it is very wise that this should be the case. He has brought out the idea very clearly, much to my gratification, that this business is in its infancy. that is is undergoing the process of selection and the fittest is going to survive; but so far, certain styles of deformed bars and other reinforcing materials have apparently a long advantage over their competitors, simply through the force of advertising, as the author has said. Now, this process of selection is going to continue, of course, nobody can prevent it. One of the strong influences in that process is going to be the question of cost.

I think it is on account of this very question of cost that so much hard steel is being used today, for the following reason: A form of deformed bar was discovered that is soft steel.

* Inspecting Engineer, Jones & Laughlin Steel Co.

and yet is of perhaps double the strength of soft steel. I refer to cold-twisted squares. When the cold twisted squares appeared, it became clear to those who were exploiting plain and deformed bars of ordinary elastic limit, say 35 000 lb. per sq. in., that here was a foe which would require a great deal of attention. The only way that this competitor could be met on a common ground would be to raise the elastic limit of the product the manufacturer in question was making. The only way to raise that elastic limit was by raising the carbon. The carbon therefore was raised, and the bar made brittle in a conscienceless way, I think. This is one of the things that will have to disappear before the law of selection is done with its work.

Now, I am a steel man and have seen a great deal of cold-twisted steel manufactured. I am no more interested in it than in any other steel product, yet it does appear to me that this form of reinforcement has a number of features about it that are going to make the cold-twisted square one of the survivors in this warfare of competition. The first element is cheapness of manufacture; the second is an elastic limit that cannot be approached by any other process. There are other very good reasons why the cold-twisted bar should succeed, and one of them is the very reason that was named as one of the detriments by the author this evening. I judge his illusion to torsional shear was aimed at twisted squares. Let me say that I have tested a great number of these bars and have found that the greatest strength is right at the surface. Therefore the cold-twisted square opposes its very greatest strength to torsion. It has been claimed that a square will actually pull out like a screw and untwist when stress is put upon it longitudinally. I know this to be false, and for the very reason that I have named. A further good feature of the cold-twisted square is the fact that the bar is known to be perfect; if it were not, it would not stand the twisting action. It has the mill scale removed from it in the process of manufacture, so that bond is never imperfect. It is a bar that can be bent at the end in hook form or any other form desired by engineers, be-

cause it is soft; it is soft steel and yet it has the enormous elastic limit of at least 60 000 lb. per sq. in., in the smaller sizes perhaps 75 000 lb. or even higher,—this for steel of the quality, before twisting, of ordinary medium structural steel.

The time has arrived for engineers to realize that high carbon means brittleness, and that they are taking chances when they write specifications which permit or require the application of high-carbon steel bars in any form, plain, hot-twisted or otherwise deformed. No specification is a safe one which calls for a value for minimum elastic limit as high as 45 000 lb. per sq. in. in any style of hot-finished bar, because this elastic limit can be created in only one way—the addition of carbon.

Specifications should not attempt to provide for both cold-twisted bars and hot-finished bars in the same physical requirements. If plain bars or other hot-rolled sections are favored, the physical requirements of the specifications and the unit stress in the design should be made to suit steel of safe carbons, say the standard structural grades, the elastic limit of which is about 35 000 lb. But if cold-twisted bars are to be included, an appropriate specification would call for minimum elastic limit of 55 000 lb. per sq. in., with cold-bending test 180 degrees around a circle twice the size of the bar; and the quantity of steel to carry the required load may be reduced proportionately.

THE AUTHOR: My objection to the twisted square is the fact that it is a deformed bar and consequently has the drawbacks of other such bars. The twisted squares have a tendency to crush or rather shear the concrete along their periphery just as do other deformed bars.

Of course, as Mr. Shuman suggests, they can be anchored at the ends with a hook or some other device and in that case they might be good to use, provided that every bar could be guaranteed to be perfect. However, contractors use the square twisted bars as deformed bars without end anchorage, in which case I strongly object to their use since I would class them

with those having the worst kind of deformations. With an end anchorage the case is different and they may be used.

As for the torsional moment which, as I stated, may be a result of some deformations, I would like to point out that twisted bars would be most likely to produce it. This torsional moment would, in my mind, be due to the fact that the stress cannot jump from one twist to the next through the concrete. Tension in the rods is a continuous stress and it would have to follow the shape of the bar, that is a screw like line, except in the core where it may follow a straight line. If this tension follows a screw like line it seems to me that there must be some internal stresses due to this fact since we know it to be the case when a round rod with kinks is placed in concrete.

This is my opinion and for the reasons given above I think it justified. It is hard to prove, but I think it just as hard to deny giving good reasons for it.

However, the stress involved is of a secondary nature and the other stresses previously mentioned are enough to justify the exclusion of deformed bars in concrete work.

Mr. V. R. Covell*: Thus far in the bridge work in Allegheny County comparatively little reinforced concrete has been used. Three small bridges have been constructed with concrete floor slabs reinforced with round rods, hooked into the steel work at the ends; one small bridge has been constructed with deformed bars and the sidewalk slabs for the bridge over the Ohio River at Sewickley are designed of reinforced concrete, using a wire mesh fabric anchored along the longitudinal sides of the slabs.

The Oakmont abutment of the bridge nearing completion over the Allegheny River is constructed with reinforced concrete wing-walls faced with sandstone masonry. The wing-walls are reinforced with round rods, threaded at the ends and secured to angles or plates with two nuts at each end. These rods are so bent as to bring the steel near the outside of the slab at the center of the panel and near the inside at the anchor

* Deputy County Engineer, Allegheny County, Pittsburgh.

angles or plates. The plates and angles are tied from one wing-wall to the other with rods having forked eyes at the ends and turnbuckles for adjustment.

Personally I favor the end anchorage and smooth bars in reinforced concrete.

MR. WILLIS WHITED*:: I did not expect to take part in the discussion tonight, but there are one or two points that might be brought out in this connection.

One difficulty with some bars that are on the market for concrete reinforcement is that they are made from inferior stock or old rails and are, therefore, brittle and unreliable. The quality is barely good enough to permit of its being twisted, and if any attempt is made to forge it, or to bend it cold, it is apt to crack, in which case the contractor is liable to try to weld it, but with very indifferent success. It is rarely possible to make a satisfactory weld in that kind of steel. Twisted bars, if made of good steel and properly handled will do very good work. Some express a fear that twisted bars will pull out of concrete, but I think such fears are groundless, as the irregularities in the bars and the friction in the concrete will prevent that even without adhesion.

Sometimes it is necessary or advisable to anchor the ends of bars. The idea of bending over the ends of the bars to form a hook two or three inches long, as is often done, never appealed to me, for this reason: If the anchorage is required to hold anywhere near the full strength of the bar, the bearing is mostly confined to the immediate vicinity of the bend, and the concrete is not nearly strong enough to resist that stress with a proper margin of safety. It should be bent over another bar which should be large enough, of proper strength and have sufficient bearing so that the concrete will not be overstrained and so that the bar will not pull around the anchor; or the bar must be secured in some other effective manner.

Whatever anchorage is provided it must be so arranged that the full bearing will be against the anchor and not against

* Asssistant Engineer, Bureau of Construction, City of Pittsburgh.

intervening concrete, which might be greately overstrained. If a rod is anchored with nuts and washers, a nut should be put on each side of the washer to insure that the nut shall bear on the washer and not against intervening concrete.

I am inclined to think that the bar the author has described would be improved if the loops were made as nearly semicircular as practicable, in order to distribute the bearing on the concrete over a larger section of the bar.

THE AUTHOR: The semicircular form would be better than bends made at right angles, but it offers some practical difficulties in bending and that is why it is not adopted. The square bends in the loop are not really square, but are bent on a radius which is increased with the diameter of the rods. It is what might be called a rational loop.

So far as crushing the concrete is concerned, I do not think there is any danger of its occurrence and I am speaking from experience. We have made, quite recently, several tests which prove this conclusively. These tests were made with 3-4 in. rounds and 3-4 in. squares embedded in concrete blocks, and a progressively increasing load was applied to the rods as near to the face of the block as possible.

All the experiments we made have shown that rounds or squares will carry very nearly the same load before the concrete crushed under the bearing, the average being about 12 000 lb. When this load was reached the concrete just began to give signs of crushing, but did not crush until the load reached about 17 000 to 20 000 lb., if my recollection is correct.

These tests were made at the Lehigh Valley Testing Laboratory, and 18 tests were made, I think, with concrete one, two and three months old, of the usual mixtures, 1:2:4 and 1:3:6. If concrete does not crush for a 3-4 in. round, which is good for 16 000 x 44=7040 lb. tension in practice, until the load reaches 12 000 lb., it shows conclusively that there is no danger in the loop anchorage with rods bent at right angles.

I would like particularly to point out that the adhesion

has been entirely disregarded in the above figures and that it would greatly decrease the compression at the anchorage.

MR. J. A. FERGUSON*: I do not want to be understood as advocating any particular kind of reinforcing bars, but I rise to the defense of the deformed bar since it seems to have so few friends tonight. In doing so I would defend the use of rationally deformed bars only. So many bars have been gotten up with the sole purpose of evading patents and having a patented bar to exploit which, as has been pointed out by the speaker of the evening, will not bear critical inspection by an engineer experienced in reinforced concrete work. By a rationally deformed bar I mean one the properties of which are based on practical experience and sound judgment. Speaking generally from experience with a few kinds of smooth and deformed bars, from considerable study of structural design as practiced by the best concrete engineers, from results of tests, and from the behavior of structures designed by myself, I believe the deformed bar will give consistently better results with the average kind of work done by contractors. For instance, on one piece of construction work, I was able to twist with my hands a round rod embedded five feet in a concrete pier, and on another, to pull out a square untwisted bar embedded three feet. Deformed bars have not only the adhesion, which is a considerable portion of the total bond, but they have the additional advantage of the anchorage offered by the projections. These last bringing into play the shearing strength of concrete which is at least one-half its compressive strength and much higher than the bond only.

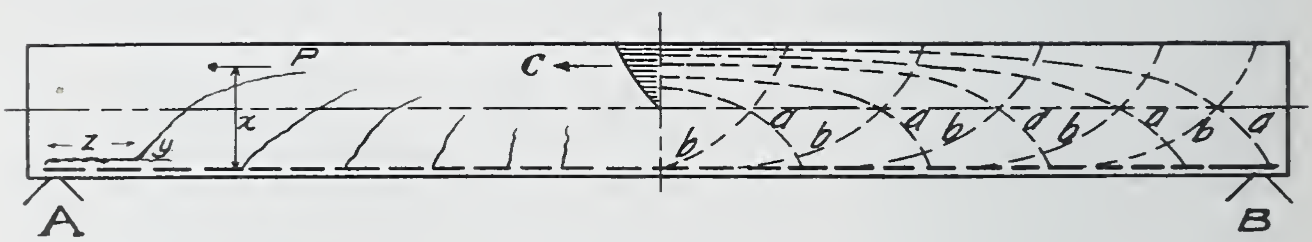

Fig. 11.

With regard to the stirrup idea, the need of diagonal reinforcement, and the internal stresses in a reinforced concrete beam; the following will probably throw some additional light.

* Assistant Engineer, Bureau of Construction, City of Pittsburgh.

Referring to Fig. 11, the steel being at the bottom of the beam, the concrete in compression, greatest at the top; it is found that the lines of maximum compression follow the direction of the lines *a*; and the lines of greatest compression start close together at the point of maximum bending moment and passing along the beam, end at the steel becoming separated as they do so. I have never been able to demonstrate it mathematically but I suspect that the amount of this separation is an indication of the amount of diagonal tension present in a beam uniformly loaded. The lines branch out from the steel all along its length and curve upwards. In the case of a homogeneous beam these lines will be an exact reproduction of the lines *a*, except that they are reversed in direction. Lines *a* and *b* cross at right angles. If this were not the case, one of them could be resolved into components acting along and normal to the other; thus tension and compression stresses would be unequal, which is not the case. They cross the neutral axis at 45 deg. from the horizontal, for lines of maximum shear cross lines of maximum compression and tension at 45 deg., and the maximum shear at the neutral axis is horizontal. The lines *a* indicate a kind of arch action in the beam. Each fiber of the beam at the center line being the crown for an arch whose abutment is at the steel. From this the vital necessity is seen for a good abutment, furnished either by the adhesion of concrete to steel or the adhesion combined with mechanical abutments furnished by the deformation of the bars. A deformed bar, if correctly designed, furnishes a more trustworthy abutment than a round bar which offers no mechanical resistance to slipping and thus, in the exigencies of rapid execution of work and uncertainties of quality of workmanship found on the job, the superiority of deformed bars over round bars for many cases is seen, since there is an anchorage all along the bar instead of at the end only as advocated in the paper of the evening.

Proof of the correctness of this analysis is shown in tests of beams made without web reinforcement. As a typical case I cite those made by Prof. Arthur N. Talbot at the Univer-

sity of Illinois, published in the University of Illinois Bulletins, series of 1905-1906. The broken lines shown in Fig. 11 indicate cracks found in beams at failure as illustrated in the Bulletins referred to. The lines shown follow a course at right angles to the lines *b* in general. It will be readily seen now that diagonal reinforcement is necessary. On account of the horizontal thrust of the arch action it will be noted that such reinforcement should be fastened with absolute rigidity to the horizontal steel to prevent slipping. Vertical stirrups do not fasten rigidly to the horizontal steel, thus they are subject to slipping and do not aid as abutments for the arch action. They do not follow the lines of maximum tension and therefore must be designed more heavily than if they did and so they are not efficient as reinforcements.

At the left end of the beam, in Fig. 11, is shown a failure which frequently occurs. A crack forms just above the steel, extends along it for a distance and then upward into the beam. At failure the concrete seems to lift off the steel along this crack. This can be explained as the result of slipping of the bar. The compressive force is concentrated at P with an arm x forming a couple which must be resisted by a couple having a downward stress at the point y where the crack starts upward, and an arm z as shown in the figure. Here the concrete is thrown into tension vertically just above the steel. A vertical stirrup, placed so as to apply its force at y and anchored securely at the top will effectively resist this tendency.

The Author: The lines of maximum compression, it being understood that they are the imaginary lines joining the points of equal compression, as shown in Fig. 11 are not correct.

Referring to Fig 12, which represents a beam uniformly loaded, it is well known that the maximum compression will be at the center of the span along the plane *ab*. The maximum maximorum compression will be at the point *a*, and this compression decreases to zero at the neutral axis, straight line or parabola. If another section plane *dc*, is taken through the beam the maximum compression in that plane will be at the point *d*,

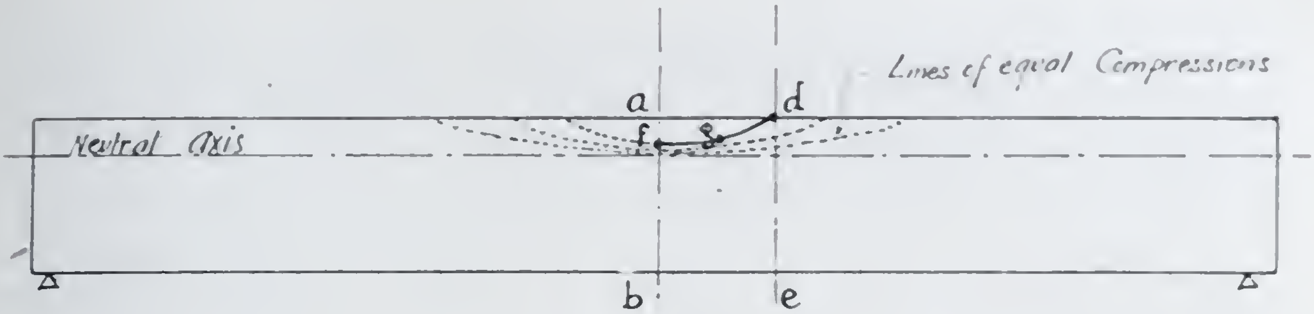

Fig. 12.

and it will be possible to find along the plane *ab*, a point *f*, of compression equal to that at point *d*. In another section plane between *ab*, and *de*, we would find a point *g*, of compression equal to that at points *f* and *d*, and the curved line joining these points will be a line of equal compression.

As far as arch action is concerned it probably will exist in deep beams of short span but it not likely to happen in shallow beams of long span. However, this arch action has nothing to do with the lines shown on Fig. 11. It will be noticed that Fig. 11 shows *arches* with their crown above the neutral axis, while if the arch action exists, the crowns of the arches are not necessarily above the neutral axis.

Fig. 13 shows this arch action. The abutments furnished by the deformed bars are inadequate for arch action. There will always be a horizontal component *H* of the thrust *T*, and a tendency of the concrete to slip along the rod, and it is a question of how much arch action will exist and what will be the value of the horizontal component *H*. If we are to figure on an arch action at all, why not make an arch instead of a beam right at the start?

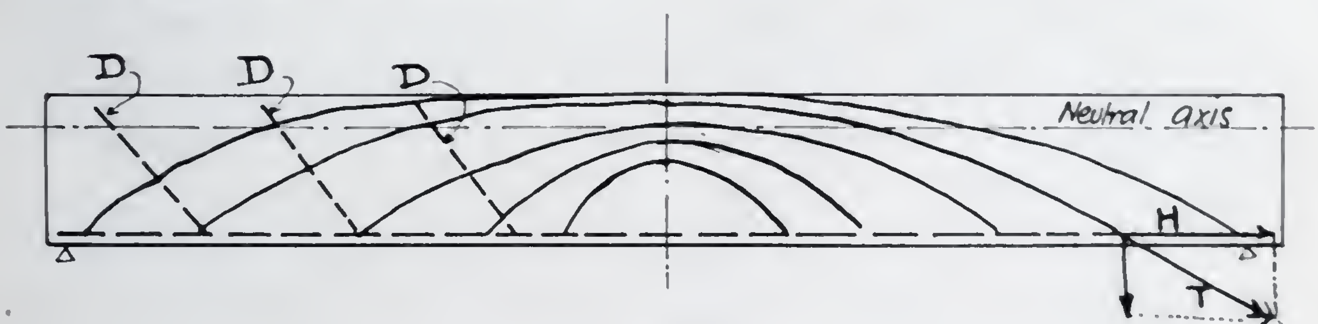

Fig. 13.

However, the only reliable abutments in the case of an arch action will, I think, be the diagonal shear members *D*.

In this case if they are normal to the thrust T, there is no horizontal component and no tendency to slippage of the rods. If they are not quite perpendicular to T, they will be very little out of it and the horizontal component will be small. It is of course necessary to have the diagonal shear members properly anchored at the ends if we are to consider them as abutments.

The experiments made by Prof. Arthur N. Talbot strongly confirm, in my mind, all the points brought out in what I have previously said and I am more than ever of the opinion that the anchorage should be made at the ends and at the ends only for the reasons heretofore given.

MR. J. A. FERGUSON: In the case of a concentrated load, your diagram is shown correctly; but I think you will find by referring to Merriman's Mechanics that his lines of compression for uniform load follow different directions than in the case of a concentrated load.

PROF. J. HAMMOND SMITH*: I think Mr. Ferguson is correct in his first statement that these lines represent the direction of stresses of maximum compression, while the other lines, which cross the lines of maximum compression at angles of 90 deg., and the neutral axis at angles of 45 deg., show the direction of lines of maximum tension.

This is true for rectangular beams of homogenous materials and is also approximately true for beams of reinforced concrete. See Merriman's Mechanics of Materials, p. 273.

THE AUTHOR: There is a large difference between the direction of the stresses and the lines joining the points of equal compression which I understood Mr. Ferguson meant. The direction of the principal streses are as shown in Fig. 11, but yet not correctly.

The lines of the principal stresses are the combinations of the bending stresses with the shearing stresses and curve as shown, but the ends of the curves become normal to the top and bottom of the beam for the following reason: At the center of the span the lines of principal stresses are horizontal

* Department of Civil Engineering, University of Pittsburgh.

and curve upwards or downwards at the ends and they have vertical and horizontal components at each point except at the center of the span where the maximum longitudinal stress occurs and at the ends where the maximum vertical stress occurs.

However, the discussion about the arch action is in no way affected and I maintain that deformed bars will not give the required abutments any more than plain rods will. Diagonal tension members only will give the required abutments.

A truss action might also be brought in and is more likely to be true for any beam, especially for those of shallow depth and long span. It would be easy to point out that diagonal tension members with a positive end anchorage are still absolutely necessary in this case, and that deformed bars of any kind would fail to give the proper anchorage for the reasons pointed out in Fig. 6, sketch *b*.

MR. H. H. RANKIN*: In tamping the concrete into the forms holding the rods, is there not a tendency for the rods to spring when the concrete is tamped around them and then afterwards gradually come back into place before the concrete gets hard leaving cavities underneath the rods?

THE AUTHOR: I do not think this likely to happen because the rod would spring back to its natural position while the concrete is very wet and before it is hard enough to leave a chance for a hole underneath the rod. However, the remark is, I think, very good and brings out the fact that a "unit" system is preferable to others. I mean a system in which the rods are so tied together that they cannot spring or get out of the location they have been assumed to have.

MR. H. H. RANKIN: Do you attempt in any way to overcome this tendency to form air pockets, and do you make a practice of tamping?

THE AUTHOR: We depend on gravity to carry the concrete in around the bars, as here in the United States all contractors use a very wet concrete. In Europe, tamped concrete is used which is not as good as the wet concrete. It is with

* Civil Engineer, Park Bldg., Pittsburgh.

deformed bars that air pockets are found. In this country the concrete is usually rammed between the rods by means of another piece of rod. It is not tamped except in very exceptional cases, or when it has to be made rather dry. A number of contractors do not even ram it at all unless there is a chance for air pockets.

Mr. J. W. Todd: I would like to have reconciled two statements that were made, one by Mr. Toupet that the tangential shear was perhaps 150 lb. per sq. in. for pulling the rod through the concrete; and another statement by Mr. Ferguson that perhaps you could pull out a bar embedded in five feet of concrete.

The Author: This remark is well founded and I would say that if a contractor embeds a rod five feet in concrete which can be pulled out after the concrete has set, the contractor might as well leave the business because he does not know it.

Mr. J. H. Smith: I would like to ask the gentleman if he knows whether that bar was rusty or not. If the bar was rusty, the concrete will not bond whatever the shape of the bar. The carbon in steel for reinforced concrete should be very low and the steel should bend double, cold. If it will not stand this test without cracking, I believe it is too high in carbon. The practice of cutting threads on rods for nut and washer anchorage reduces the net area of the rod nearly one-third, so that if a 3-4 in. bar is used, you practically would only have a 5-8 in. bar.

The Author: I think that since an anchorage is designed to replace the adhesion which may be lacking, it is well to design it to carry the entire tension as far as this is possible.

Of course I agree that the anchorage, together with the adhesion of the concrete to the rod, will be sufficient in probably all cases, however, the point is well brought out. But a thread, two nuts and a washer, is a very expensive anchorage and a welded washer would answer just as well or better, since the area of the rod is not reduced and at the same time is a good deal cheaper.

MR. WILLIS WHITED: Generally speaking, it is not necessary that the anchorage should hold the full strength of the bar, but if it is necessary the bar may be upset or a different anchorage may be provided.

MR. J. A. FERGUSON: Replying to the question about the rod embedded five feet, is was not rusty, the reason it could be pulled out was because the cement mortar had partly run away from the place where it was embedded.

THE AUTHOR: I can only repeat what I said before, that the contractor did not know his business. Concrete is supposed to contain a certain amount of cement, no matter where the the concrete is put, or what it is used for. Cement is the sinew of the aggregate.

[Editor's Note: The Etude Experimentale Du Ciment Arme, by R. Feret, contains an excellent bibliography of reinforced concrete covering about 150 pages.]

THE GAS HOLDER

By Lewis Vincent*

It is seldom that the gas holder is accorded recognition by an engineering society other than Gas Associations, never in the writer's experience. While descriptions of bridges, buildings and machinery are presented in various papers here from month to month, the gas holder has stood by, a majestic outcast, unrecognized and little understood, save by the few distinctly interested in it, or by those who live in its shadow and heap maledictions upon the day that brought such a monster to obscure their light and lessen the value of their property.

It is, therefore, with some diffidence that I present the subject before a body of men so well informed in other lines, harassed as I am by the question of how best to present it. It is a large subject, one to which more than one evening should be given to completely cover the ground. I have thought best to give a general description of the structure, and any special points which you care to have enlarged upon, may be brought out in the discussion.

With the general use of gas for lighting, well established over a century ago, came the need of reservoirs in which to store the surplus gas manufactured. These were at first crude tanks made of cast iron, brick or timber and sometimes were simply brewers' vats. But with the growth of the gas industry, the evolution of the gas holder commenced and continued from one stage to another until it has reached a high stage of development, and a justly high place in the scope of the engineer.

The consumption of gas does not go hand in hand with its production. Hence the gas holder was first called into use as a storage reservoir to take care of the surplus gas manufactured and to tide over a period of enforced idleness of the manufacturing plant due to break down or needed repairs and to lessen the embarrassments caused by labor difficulties. With the introduction of the exhauster, a second use was found for the gas holder in storing up the power with which

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* Chief Draftsman, Gas Department, Riter-Conley Mfg. Co.

to force the gas through the mains and distribute it throughout the city. This is the two-fold purpose which the gasholder served and still serves: to store up the gas and to store up power for its distribution.

When need came for larger gas holders, the simple tanks at first used, gave place to tanks of a more intricate design and constantly increasing attention was given to the design. Pits, lined with brick, stone, and concrete, were next used. These were filled with water and a large inverted cylindrical vessel, with its bottom open was used for storing the gas, this vessel rising and falling as the gas was alternately pumped into it or withdrawn. Only a simple cylinder was used, the capacity of the holder being limited by the diameter and depth of the tank built. With the introduction of telescoping, the capacities of the holders increased to an enormous extent and the gas holder developed to the type which has ever since been in use.

When gas was first introduced in London, the capacity of a single holder was limited by law to 6000 cu. ft., on account of the supposed danger involved in storing up large quantities of the explosive and inflamable gas. At the present time gas holders in our large cities vary from 1 000 000 to 6 000 000 cu. ft. capacity, to say nothing of the holder at Rotherithe, England, of 12 200 000 cu. ft. capacity, and one of 15 000 000 cu. ft. capacity at the plant of the Consolidated Gas Company, of New York City, in Astoria, L. I. These two, however, are built in concrete water tanks and are not of so much interest from a structural standpoint as the type which I shall describe tonight, the gas holder with a steel water tank, which is the most common in this country and most generally approved by engineers expert in this line. These are built up to 6 000 000 cu. ft. capacity and it is one of this size which I shall describe, this being the largest of its kind in the world, and typical in design of all others of its class. A number of gas holders of a capacity of 4 000 000 and 5 000 000 cu. ft., have been erected with steel tanks, but only one with a capacity of 6 000 000 cu. ft.

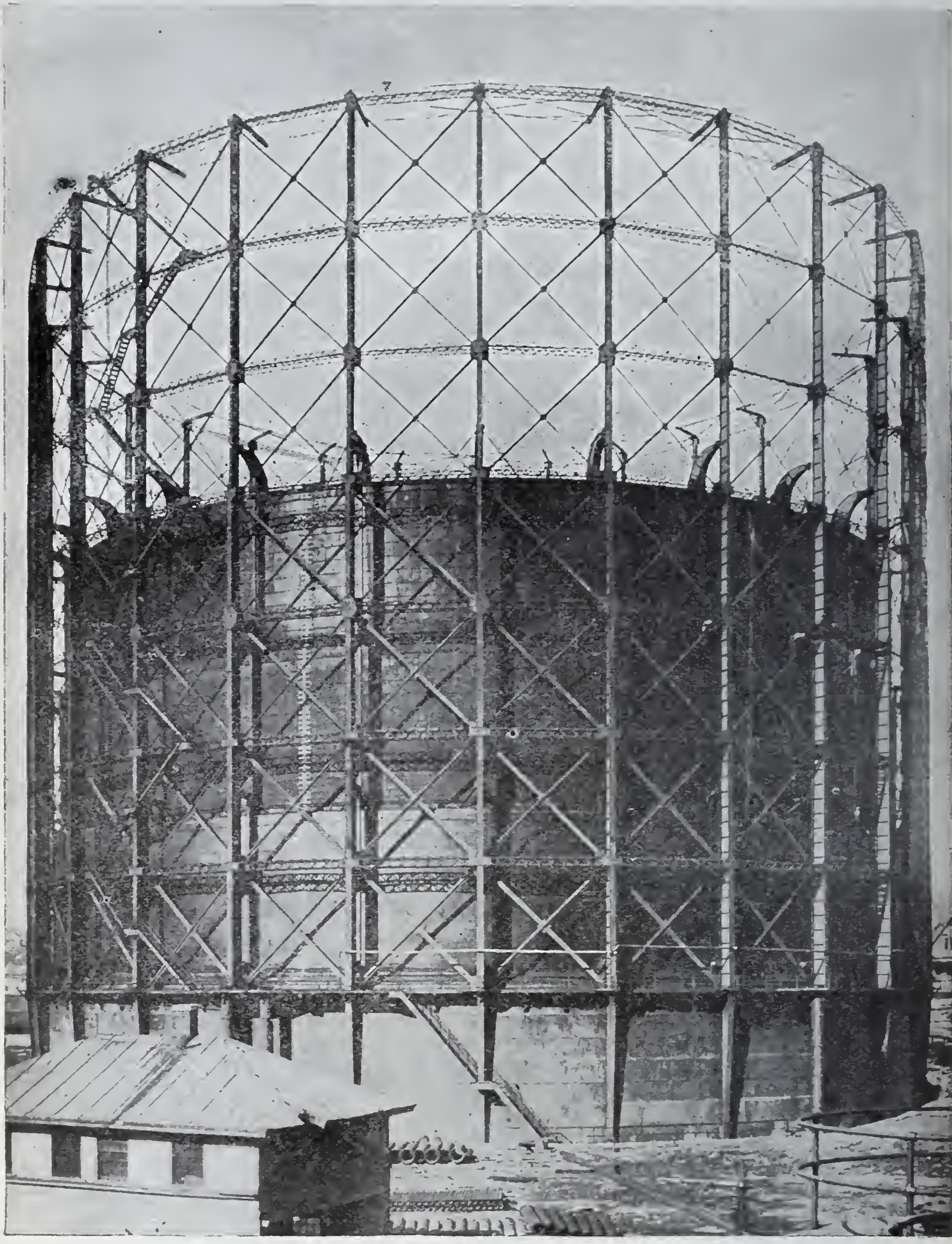

Fig. 1. 6 000 000 cu. ft. Gas Holder with Steel Tank.

The importance of these structures from an engineering point of view is readily realized from the tonnage which, in the largest, runs up to 3500 tons. The smallest that a city of any size will have is 1 000 000 cu. ft. capacity, weighing about 750 tons. The gas holder is but one unit of a very expensive plant, so it is obvious that the perfection of the design which will bring the cost to a minimum while maintaining a high factor of safety is of no little consequence.

The 6 000 000 cu. ft. gas holder erected in 1905-6, at the plant of the Milwaukee Gas Light Company, Milwaukee, Wis., is shown in Fig. 1. A gas holder of 5 000 000 cu. ft. capacity, erected in Woods Run, Allegheny, may be seen from the Sixth Street Bridge in this city. This is of the same design, differing only in its proportions which are somewhat apart from our standards. It is facetiously called the "Smoke Stack," as it is unusually high for the diameter; being built to suit the ground area available.

The principal divisions of the structure are easily seen. The lower part is the steel water tank, the columns and other structural work rising from it constitute the guide framing inside of which the holder proper, a domed cylinder of several sections, appears at partial height. These divisions, together with the inlets and outlets for gas, and the wooden crown support, form the integral parts of the gas holder.

The mechanical principles involved are exceedingly simple, though not generally understood by the layman, and are easily explained with the help of Fig. 2. This is a half sectional elevation of a gas holder made as simple as possible to illustrate clearly the working of the different parts. *A*, is the water tank; *B*, the guide frame; *C*, the holder; *D*, either an inlet or an outlet, and *E*, the wooden crown support.

The gas is forced into the holder by means of an exhauster connected to the mains at some point in the plant and enters through the standpipe above the water, filling the space between the crown and the surface of the water, the cover plates on the crown being left off until all the air in this space has been forced out by the gas. The gas is continually forced in and finally attains a pressure sufficiently great

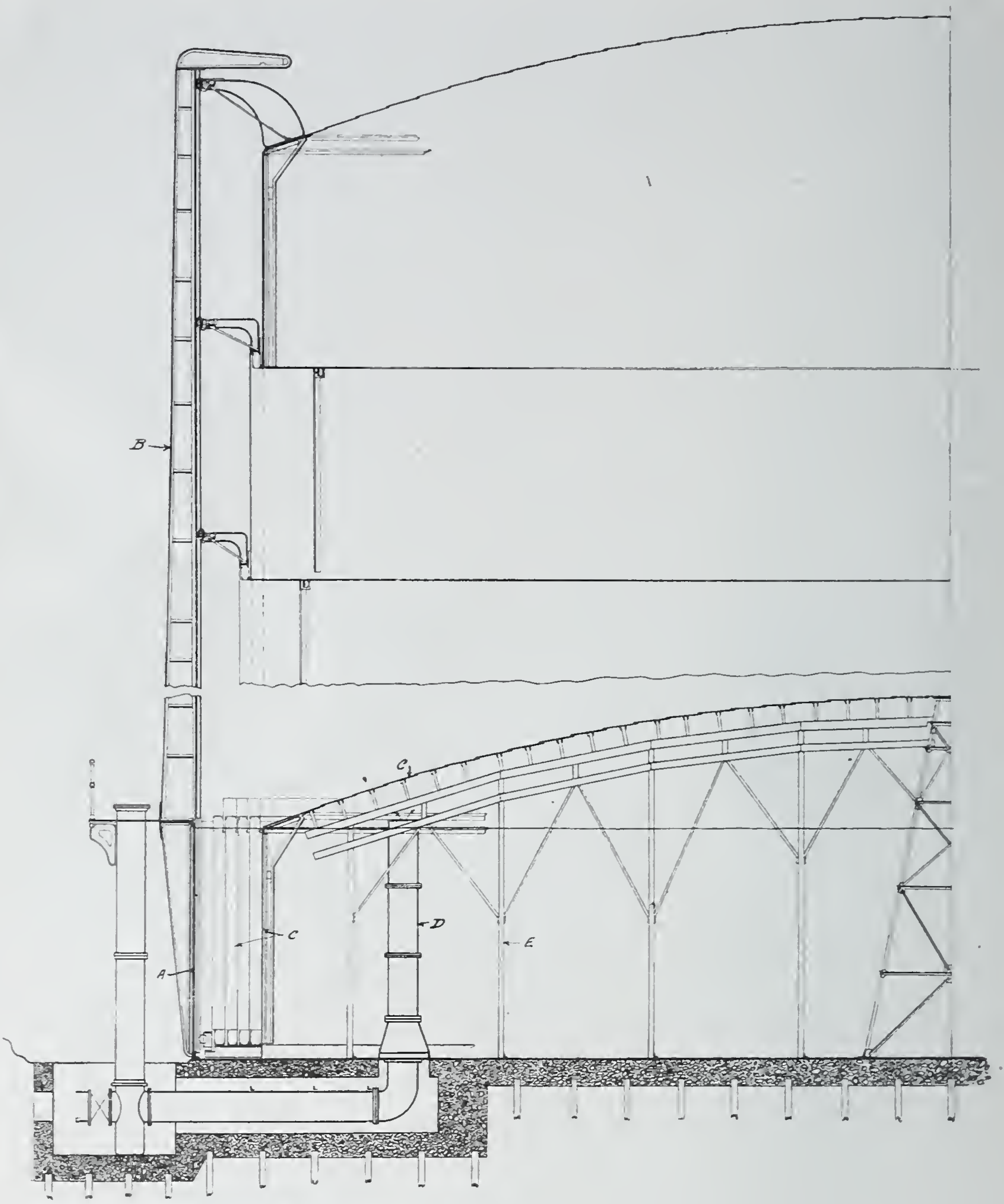

Fig. 2. Diagram showing half cross sectional elevation of a Gas Holder.

to overcome the weight of metal and the resistance against movement of the inner shell or lift, and the lift rises. The single lift was the limit of size for the early movable holders.

It will be noted how the capacity of the holder was increased by the introduction of "telescoping," which is merely the appplication of the method used in extending the different

sections of a telescope. The rising inner lift, when within a few inches of the surface of the water, picks up the second lift by means of a cup and grip arrangement on the bottom of one lift and top of the other, and carries it along in its ascent. This increases the weight to be lifted and consequently requires an increased gas pressure to carry the additional weight. As the cup on the bottom of the inner lift emerges from the water, it remains full of water forming the seal by which gas leakage is prevented at the connection as in the common *U* tube, the gas forcing the water up outside of the grip sheet until the difference in level of the water on the two sides of the grip plate is sufficient to balance the pressure of the gas inside the holder. The other lifts act in the same manner. The outer lift has no bottom and if the lower edge rises near enough to the surface of the water, the gas will overcome the pressure of the water and blow out under the edge of the lift until the pressure inside is relieved, and the holder drops back from its own weight. The gas forced into the holder has considerable bouyancy, which of itself tends to force the holder up, the specific gravity of gas being about .65, as compared with air, and the pressure from the exhauster does the rest. In this particular holder, a pressure equal to a column of water about 4.5 in. high, or 2.7 oz. per sq. in., is necessary to raise the inner lift, the total effective pressure being that exerted on a diametrical section of the lift. To raise the holder to its full height it is necessary to have a pressure equal to about 11.5 in. of water.

For supplying gas to the mains, one or two outlets of the same character as the inlet is provided. The pressure of the holder will at all times force the gas into the mains; its intensity depending upon the height of the holder. As the pressure given by a larger holder is usually too high for use in the mains, it is reduced by an automatic governor, located apart from the holder.

The crown of the inner lift is the surface of a sphere of 4200 in. radius and is made up of a center plate 6 ft. in diameter and concentric rings of light steel plates varying from 12 to 9 gauge, according to the size of the holder. The main

portion of the crown is standard and will fit any size holder. The two outer courses of plates are, however, special for each size of the holder, being designed to fit into the diameter of the lift and to resist the varying strains. This requires somewhat heavier sheets in the next to the outer course and very heavy plates in the outer course as it is here that the greatest strain comes. The outer course is attached to the holder shell by means of a heavy curb angle figured to withstand the compressive strain due to the special shape of the crown. The curb course is reinforced by a secondary curb angle located near its inner edge. It is further connected to the shell by means of plate girder legs, expanded at the top to the width of the plate. These serve to stiffen both the shell and the crown, making a rigid framework and preventing buckling of the sides.

The shell of the lift is made of steel plates, arranged in courses about 32 in. in width, the top courses being of plates of sufficient weight to withstand the bending forces due to the pull of the crown and the bottom courses heavy enough to resist the buckling force due to the cup and grip connection to the next lift. Intermediate courses are of 10 gauge plates. The cup is made of a 10 in. channel riveted to the outside of the lower course and a plate attached to the outer flange of the channel, its upper edge being reinforced by a bead bar to provide enough bearing to take the weight of the next lift. The grip is simply the cup reversed with the grip plate extending above the channel forming an apron which retains the water as it is forced up by the gas pressure within the holder. The lifts are all of the same character; the only difference being in the outer lift which in place of a cup has only a curb channel at the bottom.

All lifts are fitted with guides at the top and bottom called goosenecks and bottom brackets respectively. These are fitted with carriages containing Hyatt Roller Bearings. The gooseneck rollers run along guide rails on the guide frame columns, the bottom brackets on the lower lift between the flanges of vertical *I* beams attached to the inside of the tank and the

brackets on the other lifts run along guide channels attached to the next lift, the latter guides acting also as stiffeners for the respective lifts. These features are all well shown in Fig. 2. The goosenecks are each fitted with three rollers, two tangential and one radial, the former being double flanged and running along each side of the *T* rail, the radial roller is straight faced and runs along the face of the rail. The brackets are fitted with a single straight faced radial roller.

The most perfect contact obtainable between the rollers and guides is desired in order to transfer the wind and snow pressure on the holder evenly to the guide frame, as well as to prevent any tilting of the lifts which would throw extra strains into the guide frame, and also to insure uniform motion of the holder in rising or falling. To secure this result the guides on the guide frame and tank are made perfectly plumb. Field measurements are taken after the tank, guide frame and holder are erected and riveted up and the clearance at each point between the holder and its guides determined. The average clearance at the top and the bottom is then calculated and the goosenecks and bottom brackets made accordingly; so that when the holder is blown up and rounds out to a perfect circle, there will be close contact between all rollers and their guides.

The water tank is of special interest owing to its large size and capacity. The tank in this case has a diameter of 225 ft. 9 in., and a depth of 35 ft., its capacity being 1 400 922 cu. ft., or 10 478 900 gal. To hold this amount of water the use of very heavy plates is required, the manufacture of this tank involving probably the heaviest plate work in the country. The strain on the bottom course of plates amounts to 20 575 lb. per sq. in. To keep the plates as light as possible, thus keeping the cost down to a minimum, butt joints for the vertical joints of a very high efficiency are designed. High efficiencies are obtained by the use of very large rivets and multiple line riveting in the butts. In this tank the butt joints have an efficiency ranging from 88 to 93 percent. These large rivets render necessary powerful field riveting

machines such as will drive all rivets so as to completely fill the holes, as the high efficiency is based upon the shearing and bearing values of the full diameter of the driven rivet. Rivets 2 in. in diameter are used in the bottom course of the shell, but these rivets are by no means the limit in size for field

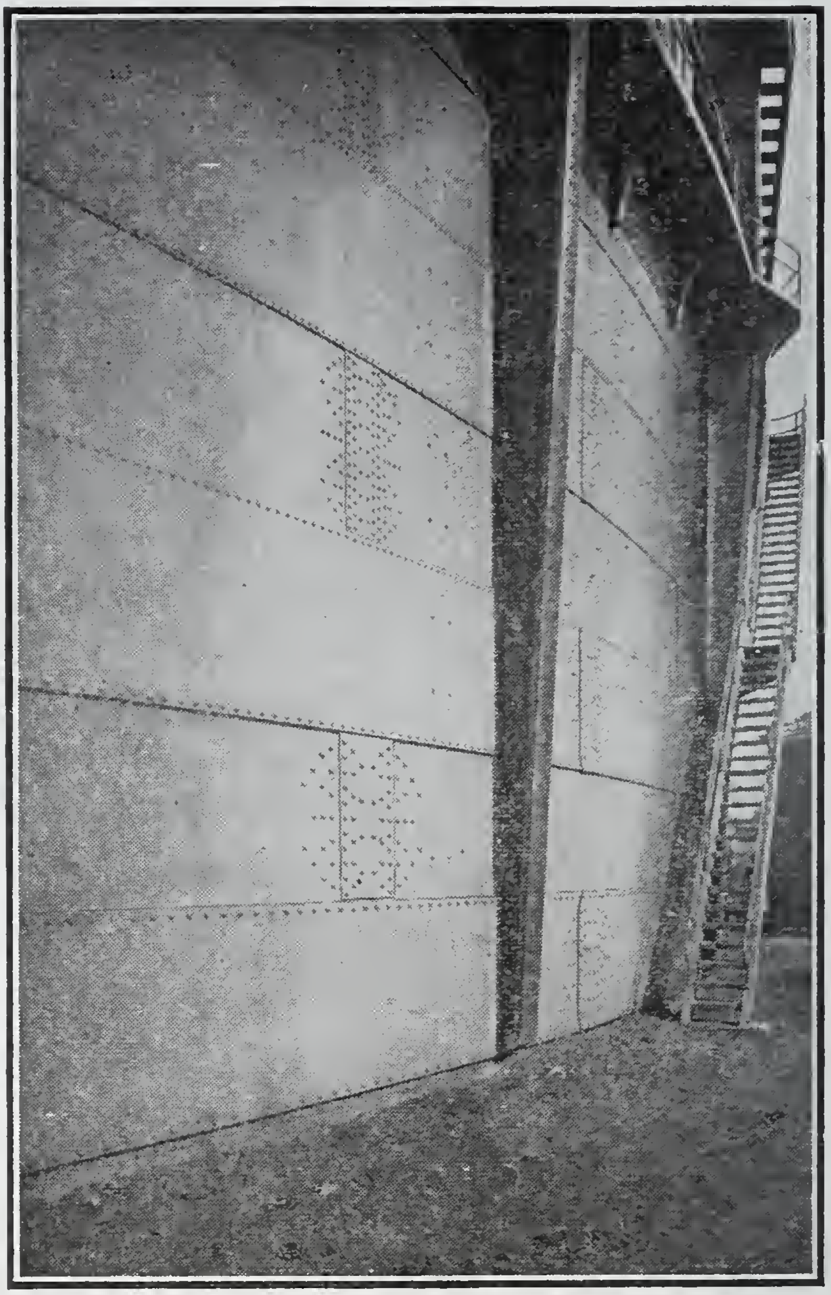

Fig. 3. Column Support and Stairway.

driven rivets as the machines in use for this work are capable of driving still larger rivets. For the most efficient driving the rivets should be so chosen that the grip of the rivet will be not over three times the diameter of the rivet in length.

The bottom of the tank is made up of 5-16 in. steel plates with a circumferential course of plates somewhat heavier, the better to distribute the weight of the tank shell and guide

frame over the foundation. Except for the circumferential course the plates are rectangular in form. Rectangular plates run out from each side of a square center plate to the outer course, dividing the bottom into quarters. The width of these plates is determined by the gap of the field riveter. Lap joints are used with a single line of 5-8 in. rivets. Landing blocks made of short *I* beams are placed at intervals of about twelve feet near the outer circumference of the bottom to provide a level base for the lifts and to give space for the bottom brackets which are attached to the under side of the cup channels. On the inside of the tank shell, vertical *I* beams are attached which, as mentioned before, act as guides for the outer lift. These are made plumb by means of connection clips made according to field measurements taken after the erection of the tank. The lower ends of the beams are placed at a constant distance from the bottom curb of the tank which is assumed to have been riveted up to a perfect circle, a very accurate assumption, owing to the nicety with which the work of laying out and drilling is done in the shop. Outside of the tank shell, at column points, vertical stiffeners of plate girder form are attached, which, while stiffening the shell vertically, perform their principal function in supporting the heavy column of the guide frame. A walk built around the top of the tank shell rounds it up, stiffening it horizontally, and provides passage around the tank. This is made of plates and angles supported on pressed steel brackets attached to the tank shell as shown in Fig. 3.

To deal exhaustively with the guide framing would require more time than at our disposal tonight. There have been several books written upon the subject dealing with the various theories of designing the guide framing of gas holders, and this is without doubt the most interesting problem in connection with their design.

The guide frame is essentially a vertical cantilever, the forces upon it being the wind pressure and the load thrown upon it due to snow unequally distributed upon the crown of

the holder which tends to tilt the holder about its center of bouyancy. The types of guide framing are various and the practice among different engineers is widely divergent even to this day, although in this country the design is pretty close to that illustrated. In the earlier holders the columns were hollow cast iron tubes, very large at the base and tapering to the top. Each column was figured to take the entire loading from the holder. Types of this kind can still be seen in this country. A curious holder was built in England the first part of the last century, using but one column. This was placed in the center of the tank and the holder was built around it, made up of two concentric shells. There have been many holders of odd design built, too numerous to mention or describe here. Holders have been built without any guide framing whatever and are still in successful operation. Holders of a capacity of 1 000 000 cu. ft. have been built in this way. Large gas holders with guide framing extending up to only a part of the total height of the holder, have also been erected; but it has been found that there is no economy in this design, the weight saved in the guide frame having to be put into the holder to take care of the extra strains due to lack of a guide frame or of part of it. The gas holder with a full guide frame is also a very much more aesthetic structure.

Mr. George Livesey of England, introduced the present type of guide framing which consists of columns of plate girder form joined to each other and braced by struts and ties forming a complete rigid cylinder supporting the holder. The main difference of opinion in guide frame design has been in the treatment of the guide frame on the one hand as a perfect cylinder and on the other hand as a collection of independent posts. A design of column recently came under my observation in which each of the columns was evidently figured to take the entire loading. They were monstrosities, great latticed girders six feet wide at the bottom. The guide framing weighed something like 250 tons more than would be the weight if designed on the same principle as that of the holder illustrated.

In the holder I have described, we have a framing which closely approximates a cylinder, and in which each column takes its proportion of the loading. The stresses are scientifically worked out and the diagonals and struts proportioned to distribute the loading to all of the columns. This is no new system of framing. It was inaugurated in England about 1880 and since then many large holders have been built on the same principles. They have stood the test of time and exceed in economy any other holder built. Many systems of diagonal bracing have been employed on different holders; but of them all, the system used in this design of holder is the simplest. The holder at Rotherhithe, previously referred to, has no struts at all, depending for stiffness upon a series of diagonals only. Other holders have been built with double and triple diagonal bracing. There have been about as many different types of guide framing in use as there have been different types of trusses designed and built. The tendency, however, is to get rid of redundant members as is the case in bridge design and to get down to a scientific design where the stresses are definitely determined and intelligently taken care of. This has not been worked out any too fully as yet. There is still need for good judgment based upon long practice as well as the ingenuity of the engineer in applying his theory of stresses to the problem.

The guide frame used for the holder under consideration is made up of columns 173 ft. high, 42 in. wide at the base and tapering to a width of 24 in. at the top. They are spaced around the tank so as to form bays about 25 ft. in width. The horizontal struts are box girders made up of four corner angles tied together by lattice angles. The struts are about 20 in. deep and have a width corresponding to the width of the columns at the point of connection between column and strut. In each bay formed by the columns and struts, double diagonal bracing made up of angles is used. The column is of the form of a plate girder on end, the front and back chords being made up of channels and the web reinforced on both sides with stiffening angles spaced at frequent intervals. They are made up in three sections to facilitate construction

and erection. A railroad rail is attached to the front chord to act as a guide for the holder. Its connection clips are gotten out from field measurements taken after the guide frame is erected and riveted so as to make the guide rail perfectly plumb. An instrument modeled after an engineers' level is used to take these measurements. Its base is attached to the bottom of the inside chord of the column and a plumb line of sight established, the measurements being read off by the instrument man from a target held at many points along the face of the column. The guide frame is designed to take a wind pressure equal to 25 lb. per sq. ft. of the entire diametrical section of the holder at its full height.

At their tops the columns are further connected by a system of wind ties, each column being connected to the fourth one from it by means of a tie bar of round steel provided with turn buckles and clevises, so that the rods may be made taut after the frame work is riveted up. These long rods are supported by cantilevers running out from the tops of the columns.

The inlet and outlet connections and the crown support need little description as they are made up of cast iron pipe and special fittings, with a steel arch to take the weight of the tank where the pipes run under the foundation. The stand pipe arising from the drip on the outside of the tank is to enable the gas company to dissolve the napthalene, a crystalline substance which at times is deposited inside the inlet and outlet pipes. This is done by filling the outside stand pipe with hot water, or steam, which dissolves the napthalene throughout the inlet and outlet systems. The crown support is a system of radial and circumferential bents made up in this case of 12 by 12 in. posts and other heavy timber. Upon this framework are rafters crowned accurately to fit the crown and keep it in its spherical shape.

In fabricating the gas holder, the most careful shop work is insisted upon. Dimensions are laid out accurately to the one-hundredth part of an inch. Holes are drilled in all but the lightest sheets. The edges of all the heavier plates are

planed and the shell plates of the tank are bent to radius in a 500-ton press. The light gauge plates in the holder shells are box annealed and all standard sheets in the holder and tank are punched with punch bars, the slightest errors in which have been eliminated by careful figuring and long use.

The erection of the gas holder is one of the most expensive parts of the construction of a large holder and it is only by the use of costly field equipment and special machinery that it can be put up in an efficient manner. Figs. 4

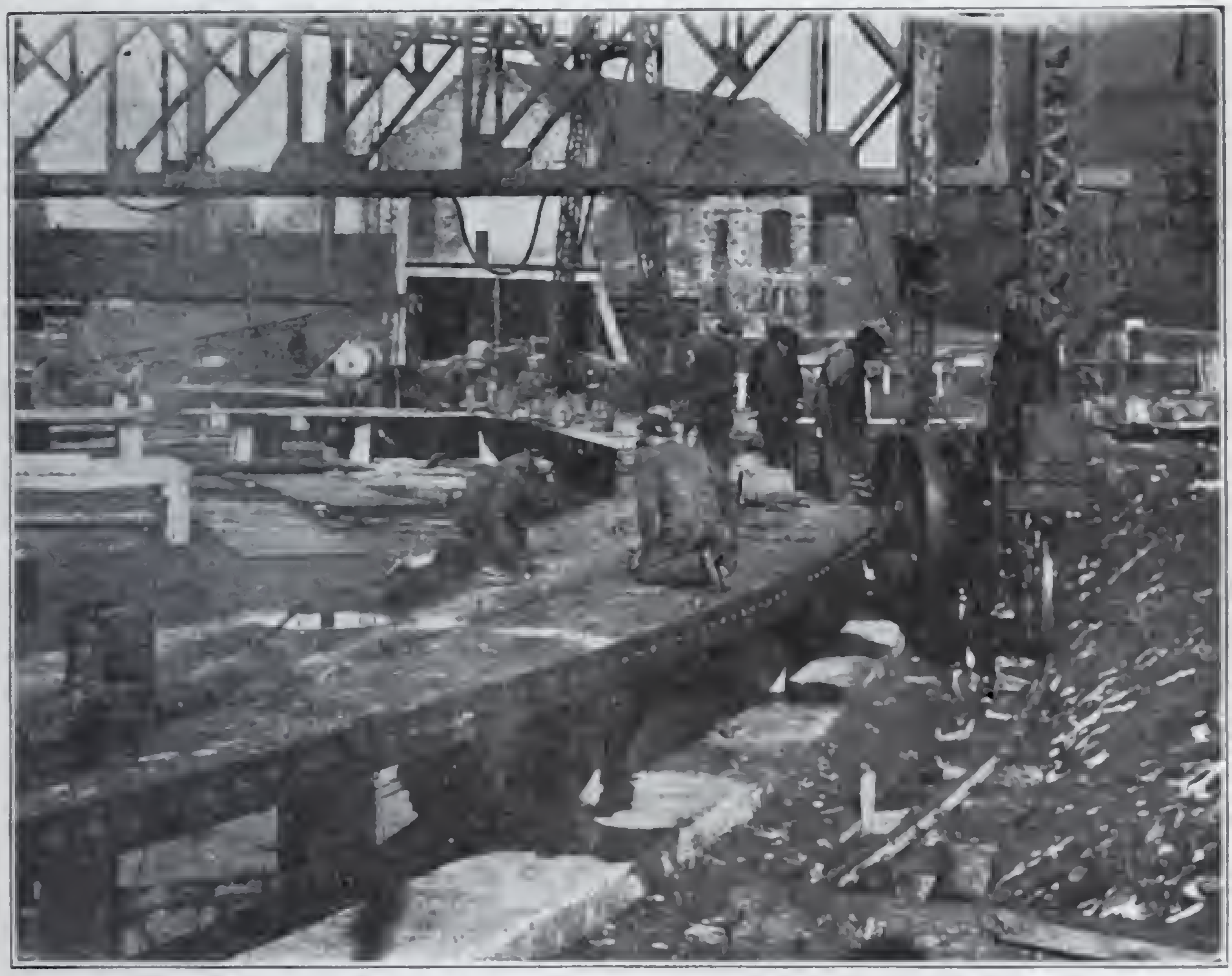

Fig. 4. Erection of Tank Bottom

to 9 are reproductions of photographs taken at various stages of erection. Fig. 4 shows the bottom in course of construction. The plates are fitted together and riveted upon the tops of "jacks," made of two boards nailed together at right angles, which keep the bottom about thirty inches above the foundation. After riveting, the bottom is lowered to the foun-

dation by means of landing screws, one of which is shown lying upon the top of the plates near the riveting machine, and which work in nuts riveted to the bottom. When the bottom is ready to be lowered to the foundation, the screws are run through the nuts, which are spaced evenly throughout the area of the bottom, to an even bearing on the foundation. The wooden jacks are then removed, leaving the bottom supported only by the screws. Each screw is then manned by a workman with a lever and the screws are turned in unison, the bottom slowly sinking of its own weight to the foundation. A layer of dry cement 3-4 in. thick is spread over

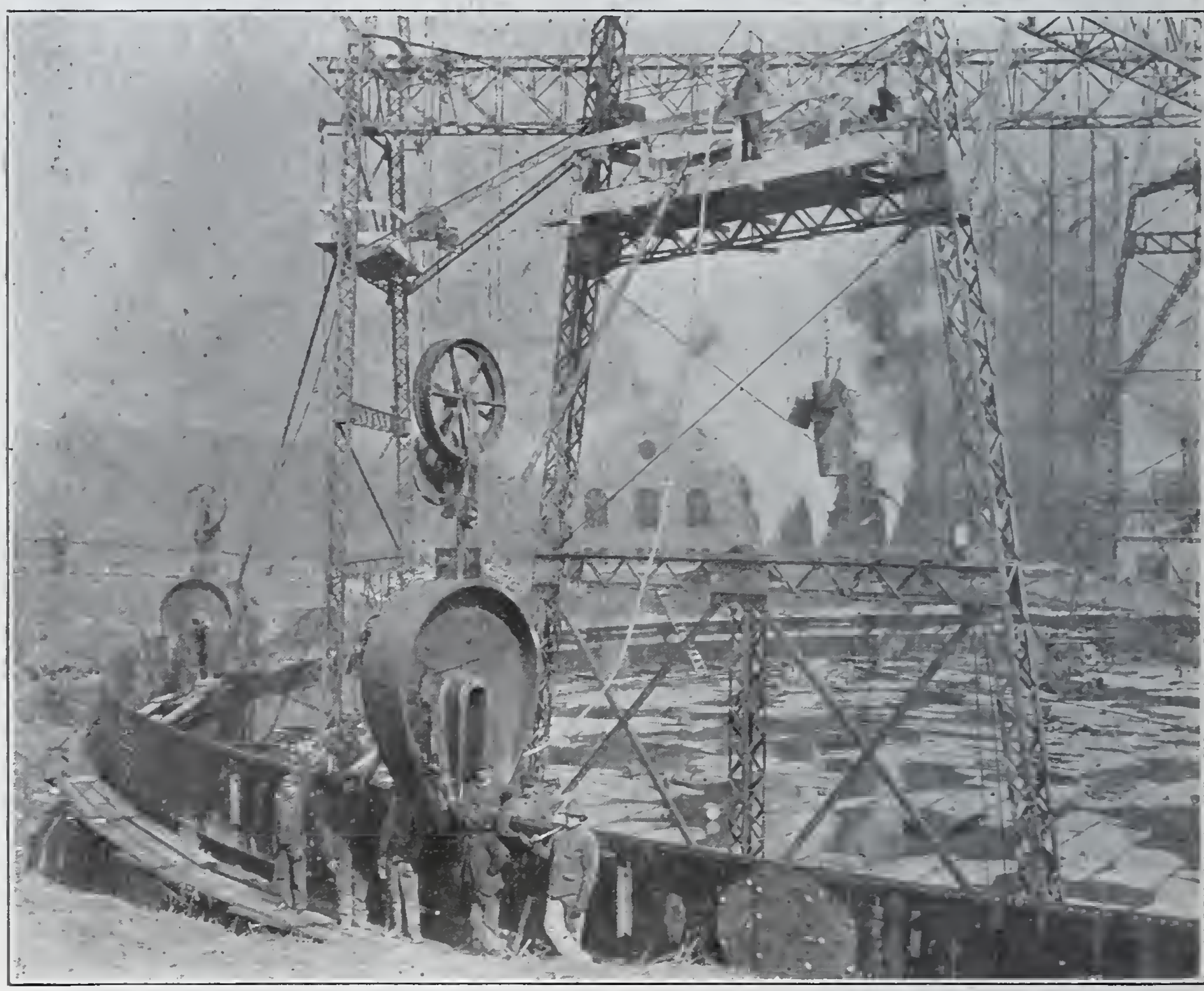

Fig. 5. Erection of Tank Shell.

the foundation before lowering, for the tank bottom to rest upon.

The riveting machine used for riveting up the bottom is also shown in Fig. 4, together with part of the trammel from

which it is hung. The trammel is a box girder, supported at the center by a king post on the center pier and at the outer end by an *A*-frame mounted on trucks which run on a circular track outside of the holder. The riveter is moved back and forth along the girder by means of a trolley upon which it hangs.

Fig. 6. Erection of Holder Lifts.

The erection of the tank shell is illustrated in Fig. 5. The riveting machine shown here is the most powerful employed on the job, being used to drive the 2 in. rivets and other large

rivets in the tank shell. The sheets are hung by means of derricks mounted upon trammels of the same character as used in the erection of the bottom and the riveting machines are suspended and moved about in the same manner. All rivets 7-8 in. diameter and under are driven cold when machine driven and the machines are used where ever possible, the heads being driven flat. All rivets which are to be driven cold are annealed in the shop before shipment.

Fig. 6 shows the holder shells about half built up. All of the shells are built up from the cups simultaneously, six or

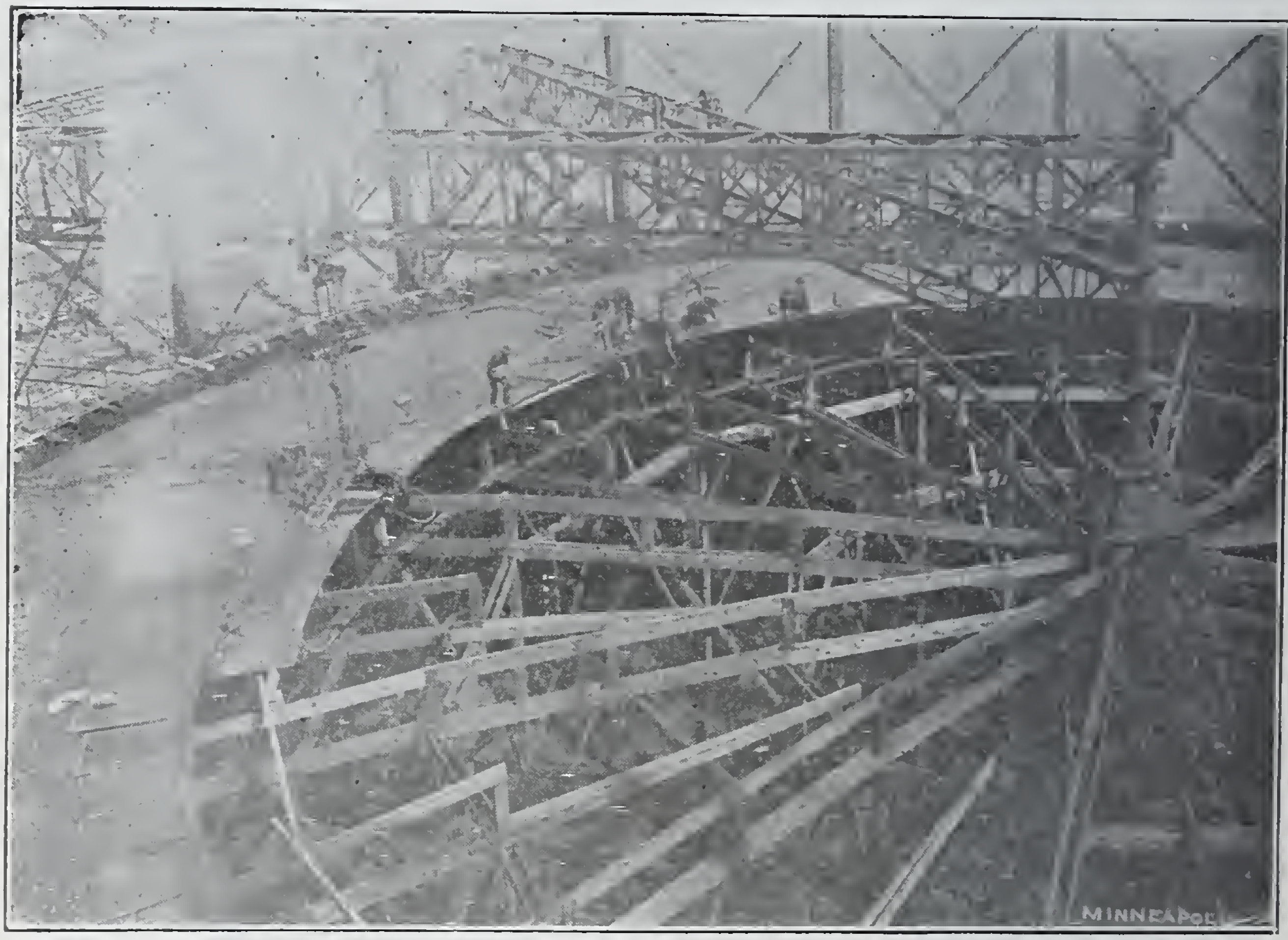

Fig. 7. Erection of Crown.

eight riveting machines being used on this work. They run by trolley along an overhead track supported by brackets on the top of the tank and on the columns, being hung upon wheels and counter-balanced to facilitate handling.

Fig. 7 shows the method of erecting the crown. This part of the erection requires probably the most careful supervision of all as the different courses must be kept at their

right height, for if too high or too low the holes will commence to run and it will be impossible to make connections as the center rings are reached. The crown riveters are also suspended by trolley from the trammel girder. Here the trammels run along a circular rail suported by the grips of the lifts.

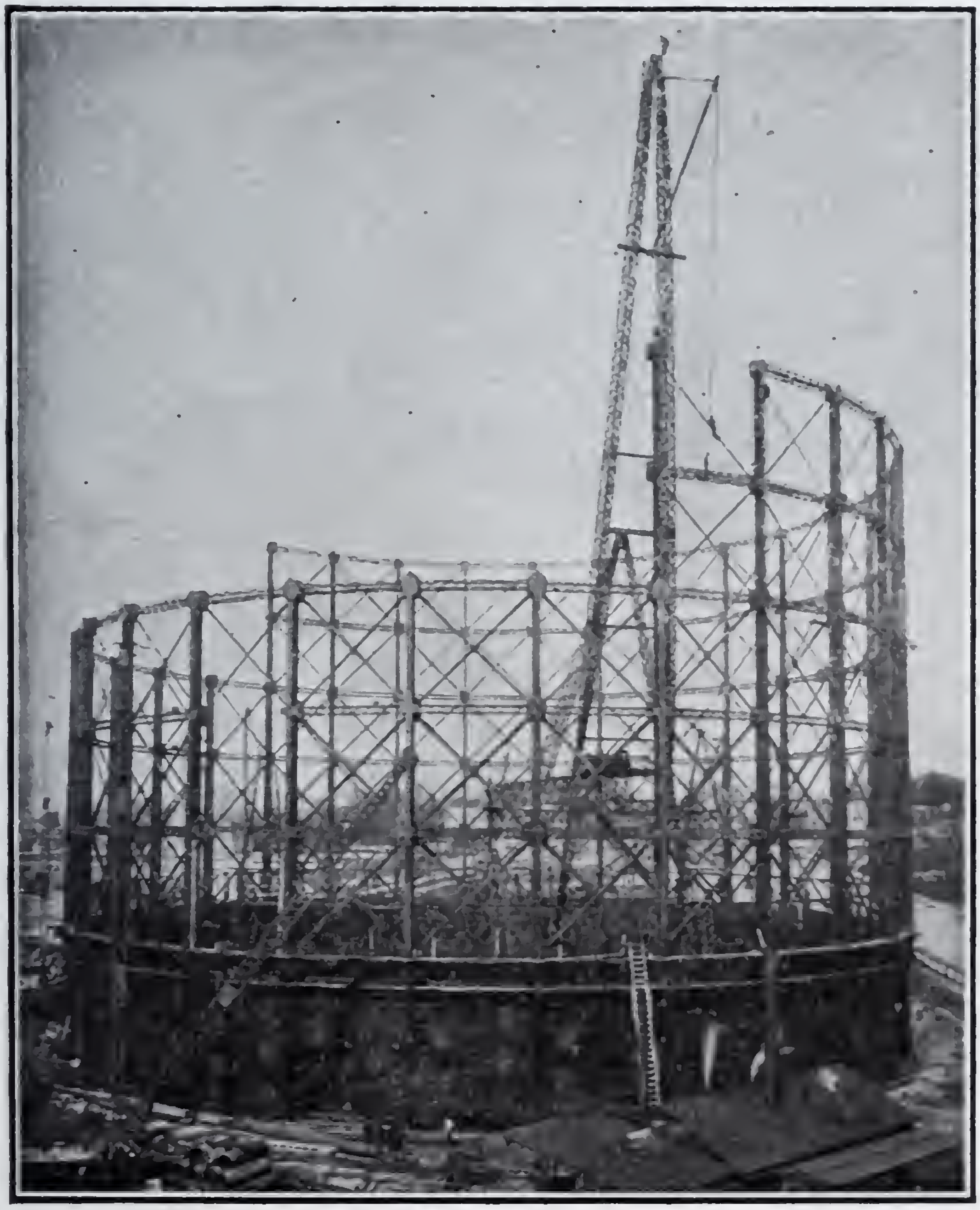

Fig. 8. Erection of Guide Frame.

The method used in erecting the guide frame is shown in Fig. 8, and needs no description as it is indicated plainly in the illustration. Fig. 9 shows top of the crown when at its full heighth and the arrangement of the wind tie rods and the cantilevers supporting them at the tops of the columns.

Fig. 9. Crown at full height, showing Wind Tie System.

DISCUSSION

Mr. S. A. Duff: I think the principal point to bring out is that in gas holder construction the details of the machinery used have received more careful study than is customary in connection with other steel construction. The slides thrown on the screen show this, and the remarks of Mr. Vincent have emphasized it to a certain extent. But I think the lesson which the average engineer should draw from this is that in this class of fabricated steel work the use of machinery for erection and the use of very accurate machinery and methods for construction have reached a much higher degree of development with great resultant economy, than is common in many other branches of the trade. That is the lesson I have always drawn from this work.

The Author: I would like to add that a special grade of steel of from .15 to .22 carbon is used in the construction of gas holders. To facilitate the bending of angles and curved shapes a very much lower value in tension than usual is used in

the plates, running about 8000 to 10 000 lb. lower. The theory is that the lower grade steel will bend very much more satisfactory than the higher grade.

Mr. R. B. Woodworth: I would like to ask Mr. Vincent whether he has experimented with open hearth and bessemer steels to compare them and what difficulties, if any, he has discovered with the bessemer.

The Author: We have never used bessemer steel so far as I know. We use basic open hearth steel exclusively.

Mr. T. J. Wilkerson: For determining the wind stresses you assume a pressure of 25 lbs. per sq. ft., using the diameter of the tank. Some engineers use 30 lbs. per sq. ft. on a reduced diameter, for stand pipes and tanks on towers.

Mr. P. S. Whitman: The common practice is to multiply the diameter of the tank by the height and take one-half of that area.

The Author: That would make the pressure used very much less. But these holders are often built on very exposed places and this pressure is assumed merely as a matter of safety and has been used in the construction of holders for a long time. It is a matter of judgment.

Mr. S. E. Duff: I think the fact has been overlooked that gas holders and ordinary tanks are entirely different structures, so that the same rule cannot be applied to both. The gas holder is suspended from a frame and the water tank is supported from the bottom.

A Member: Do you not use trusses under the crown? I should think with such large surfaces they would get bent. Have you ever had any trouble with things falling down from the top and injuring the crown? What proportion does the height of the tank bear to the diameter?

The Author: I knew of a traveler falling down on the top one time. I do not know of any gas holders in this country built with trusses. All the English holders are also built with untrussed crowns. The custom was, at first to support

the crown with trusses, but the trusses became too heavy and it was found that they worked all right without trusses.

The height of the tank is made generally about 1-6 or 1-7 of the diameter. That seems to have been worked out on the most economic basis. Over in England with large holders where they build a concrete pit one holder was built with a tank 300 ft. in diameter and only 30 ft. in height, that is only 1-10, and it worked all right. In this case that proportion was used on account of the condition of the foundation. The ground was full of water and there was so much pumping to do that they finally decided to build a shallow tank.

Mr. J. A. McEwen: Is the operation of driving these rivets cold entirely successful?

The Author: It is entirely so. But, whenever a rivet is to be driven cold it is annealed in the shop before shipment. Once in a while one cracks on a black head and has to be cut and a new rivet driven; but when the head is cut off it is found that the hole is completely filled.

Mr. W. A. Weldin: I understand the water tank is not always built of steel. I would like to ask the particular advantage of building it above ground of steel rather than using a pit in the ground made of concrete or other material.

The Author: I do not know much about the comparison of the construction but from what I have read I think the cost of the steel tank compares very favorably with the cost of a concrete tank, and also it is above ground and it is possible to find and stop any leak except in the bottom, and the bottom is supposed to be riveted up so that it will not leak. When a concrete foundation is put in the walls often crack and it is a very hard matter then to stop the leak.

Mr. R. B. Woodworth: I would like to know what is used in the way of a preservative paint for the steel.

The Author: We have tried various coatings and have found none of them very satisfactory. The principal difficulty in getting a paint for gas holders is that a liquid forms on the top of the water known as benzol, which is a destroyer of

paint. We are in the market for a paint which will successfully resist the action of the benzol.

Mr. F. R. Sites: The interior of the holder is preserved without paint because of the effect of this benzol, which is itself a preservative and protects the steel from the corrosion It is only the exterior that gives any trouble about paint.

A Member: How long will the structures last?

The Author: That has never been ascertained. The first very large ones were built in 1880 and are still standing. We have never had any complaint about any tank except once in a while one starts a leak.

Mr. F. R. Sites: An explanation of some of these leaks is the fact that the benzol eats away the paint and also eats away red lead that some builders use in the joints. Other builders sometimes use a corrosive substance to give a tight joint where two plates come together. In our practice the plates are absolutely clean, both of any corrosive substance and of paint or oil when they are brought together and the tightness of the joint is guaranteed by the efficiency of the calking of the plates.

Mr. J. A. McEwen: What is the nature of the foundation for the tank, is a solid footing used, or piers?

The Author: We use a concrete foundation under the bottom about 20 in. deep, depending of course on the nature of the ground. As a rule it is not a very heavy foundation. Around the outer edge for a distance of about 8 ft. radially, the foundation is made from three to four feet thick. This, of course, takes the greatest load, as besides the water load it takes the whole weight of the tank shell and guide frame.

Mr. E. K. Hiles: As a matter of curiosity I would like to inquire what sort of a foundation was put in for this tank at Milwaukee. I was there when they were preparing to put it in and I recall that men were there for a month making test borings over the entire site which was about 300 ft. from the river.

The Author: It was found necessary to drive piles very

thickly over the entire area which were covered with concrete, possibly a little thicker than used in the standard foundations.

MR. F. R. SITES: The tests were carried on with a view to ascertaining where the hard stratum was that would carry the load. We have been able to determine this very accurately so that piles can be cut to the right length before driving and driven with a follower to the correct level. During excavation the piles are not in the way and we excavate down to the level of the top of the piles. Thus with a follower we can drive a pile to the point where the number of blows per foot indicates a good support without having to saw off the piles after they are driven.

MR. H. H. RANKIN: Have you ever had any experience in driving countersunk rivets cold? I have known of it being tried but never successfully.

THE AUTHOR: I have never heard of driving countersunk rivets cold. With the new machines we are driving rivets cold up to 1 5-8 in. The machines also drive 2 in. rivets flat, inside a pipe 44 in. in diameter and 30 ft. long.

MR J. A. MCEWEN: Do you do any reaming in connection with shop work, or just punching?

THE AUTHOR: On this heavy plate work we do not do any punching or reaming at all, it is all drilling. The shop work is very accurate, everything is laid out to the hundredth part of an inch and very carefully checked.

MR. R. B. WOODWORTH: As I understand it the crown does not receive any stresses at all in erection, and the only stresses you get on the crown are tensile stresses due to the pressure of the gas?

THE AUTHOR: That is correct. The crown is supported entirely and the only stresses are due to the gas pressure.

MR. HENRY GULICK: I would like to ask the character of the steel used in, and the method of annealing the rivets.

THE AUTHOR: The rivets are all box annealed. They are

placed in an air tight box and heated up to the critical point, about 1650 deg. fahr. Charcoal is put in with the rivets or else gas is burned inside to get rid of the air admitted with the rivets. We use rivet steel with a tensile strength of from 48 000 to 56 000 lb.

DISCUSSION OF PAPERS

Members of the Society and also other readers of the Proceedings are urged to send to the Secretary written discussion of papers after publication, which will be printed in succeeding issues of the Proceedings. We believe that much valuable information may be presented in this way, and it is hoped that this feature of written discussion may be made a prominent one in the Proceedings.

THE WORK OF THE CLAY PRODUCTS SECTION

OF THE

TECHNOLOGIC BRANCH, UNITED STATES GEOLOGICAL SURVEY

By A. V. Bleininger*

In creating the Clay Products Section, the authorities had in mind the equipment of laboratories for the purpose of studying and testing the clay products used by the Government in its construction work, which amounts annually to about $40,000,000, and also the investigation of clays owned by the Government on its public lands. Naturally this opens up a wide field of work. There are included among the clay products used as structural materials common brick, paving brick, pressed brick, glazed and enameled brick, terra cotta, fireproofing, roofing tile, sewer pipe, conduits, floor tiles, wall tiles, firebrick and other refractories, sanitary ware, electrical porcelain, etc.

The scope of the work might be divided into three divisions: (1) the writing of specifications covering the many classes of clay products; (2) the testing of the various structural materials; (3) the testing of clays.

Old as is the use of clay materials in construction, the fact remains that we do not know very much about the subject. For this reason it has been found necessary to correlate existing and to produce new data. It is obvious, therefore, that a great deal of work remains to be done in order that the tests covering the use of these various structural products be just and fair to the producer as well as the user. Thus, for instance, there exist no definite specifications covering such a widely used product as common brick. The crushing strength, resistance to freezing, porosity, etc. of the bricks used in dif-

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* Ceramic Chemist, Pittsburgh Testing Station, Technologic Branch, U. S. Geological Survey.

By the permission of the Director, U. S. Geolog cal Survey.

ferent cities differ widely, so that materials commonly used in one city would be condemned in another and no attempt has been made to insist upon uniform requirements. Still more diverse conditions prevail in regard to all the other clay products. The work thus undertaken by the Government is certainly justified from this standpoint, and in the nature of the case is bound to be more or less fundamental.

In regard to the clay testing, simliar conditions prevail; no uniform methods are available for determining the uses for which certain clays are fitted. For instance, we are not in position at present to determine by any laboratory test now available whether or not a certain shale is suitable for the manufacture of paving brick, although this question is an exceedingly important one in many states. We are compelled to make expensive and laborious practical tests to determine this point. Again, we have no uniform tests for examining clays to be used for terra cotta, fireproofing, structural porcelain, etc.

This work of testing clay products and clays, necessarily involves both chemical and physical examination and for this reason it was found necessary to establish laboratories making possible various methods of attack. The Clay Section of the Technologic Branch established on the Arsenal Grounds in this city hence possesses chemical laboratories for the study of the chemical properties of clays and in conjunction with these, physical laboratories have been equipped in which the processes of the hardening and vitrification of clays during burning are studied in detail, and in which all physical factors entering into the final quality of the ware are considered. For this purpose there are used volumeters, shrinkage gages, apparatus for the determination of specific gravity, porosity, both true and apparent, devices for testing the plasticity and working quality, hardness, resistance to abrasion, resistance to freezing, resistance to sudden heating and cooling, heat conductivity, refractoriness, crushing strength at high temperatures, thermal expansion and other practical properties. The laboratories also possess the necessary grinding machinery,

screens, auger machines, cutting table, represses, filter presses and dryers which go to make up a laboratory of this kind. In addition, kiln space is provided for higher as well as lower temperatures and apparatus for controlling the burning process, such as pyrometers, draft gages, gas analysis apparatus, etc.

Testing machines also are provided for determining the crushing, transverse and tensile strengths of the various clay products with capacities up to 100 000, 200 000 and 600 000 lb. For pier and other tests it is hoped that a 10 000 000 lb. machine will be available in the near future.

It is evident that the ultimate properties of clay products must depend upon the changes which are brought about in clays by the effect of heat in drying and burning from the initial condition of the raw material to the final state. The writer will discuss briefly some of the points involved in the molding and burning of clay products under the following headings: Plasticity, drying behavior, dehydration and oxidation, burning shrinkage and porosity changes, fusion, strength of the burnt product, resistance to abrasion, resistance to freezing and color.

Plasticity. Plasticity, the ability of a clay to be shaped and to retain this shape, is a complex property which is the resultant of the amount and character of the jelly-like colloidal material contained in the clay and of the various sizes of mineral matter universally present in it, such as feldspar, quartz, mica, carbonate of lime, etc. Although various theories have been proposed to explain plasticity, it seems after all that we know very little about it. The general conception today is that plasticity is caused by the colloidal constituents and by no others. The presumption is, therefore, that a clay is the more plastic the more colloids it contains. However, the colloids themselves differ in regard to the sponge-like structure developed, some of the gels being in a state of greater flocculation than others, while again some are practically "set" and hence of inferior plasticity, and in addition they are influenced to an enormous extent by the presence of the various

salts, never lacking in clays. This explains the great difference of clays as regards their working behavior. Owing to the many possible conditions under which clays have been formed and transported and the many opportunities for admixture with other rock material, it is readily seen that the plastic clay base may often be of a very complex mineral structure. The question of the effect of the more or less readily soluble salts present in clays is a very vital one. It may be possible to completely change the nature of a clay by the addition of as little as one-tenth per cent of alkali or acid. The changes are due to the chemical and physical effects of these re-agents upon the colloids inasmuch as they either increase or decrease the volume occupied by the jelly-like material. The practical application of just such changes has made possible the casting of clay ware ranging from the delicate vase to the largest glass pot and all kinds of sanitary ware, replacing the more expensive molding or pressing processes. In casting, a small addition of a mixture of sodium silicate and sodium carbonate at once causes the clay to require much less water and hence cuts down the amount of shrinkage most decidedly.

The factors affecting the plasticity of clays are therefore the amount and kind of colloidal matter, depending upon its origin, the presence of salts, and the amount and size of grain of the non-plastic mineral matter.. In addition, the drying shrinkage is indicative of the amount of plastic material present since this is always greatest where the practical plasticity is greatest.

According to the work of H. E. Ashley,* the relative amount of colloids in a clay is obtained by a method depending upon the absorption of certain dissolved substances. To illustrate, on taking a certain weight of clay and shaking it in a solution of malachite green it will be found that after a short time the dark green color of the solution will have been greatly lightened since part of the coloring matter has been taken up by the clay. By means of colorimetric measurements this amount may be accurately determined. The above

* U. S. Geol. Survey Bull. 388.

investigator then reasons that the greater the amount of malachite green which is taken up by the clay the greater should be its plasticity. By taking a well known plastic clay such as the Tennessee ball clay No. 3 (Potter's Supply Company) as the standard, and plotting a curve showing weights of dye substance absorbed against varying weights of this clay, the standardization data are obtained. Taking then a certain amount of any other clay, say one gram and shaking it with 100 cc. of the standard solution of malachite green (3 grams per liter), the amount of dye absorbed will indicate the relative amounts of colloids contained in the sample in terms of the standard clay. Thus the plasticity of the clay examined should be expressed, in part, by the amount of relative colloids found. If, for instance, it should be found to contain 80 per cent, its colloidal content should be 4/5 of that of the Tennessee ball clay.

Since, however, according to the statement made above, the amount and sizing of the non-plastic constituents is a factor in determining the resultant plasticity some value must be obtained which expresses this relation.

For this purpose a so-called mechanical analysis must be made which consists in separating out the various sizes by means of sieves and elutriating cans. For this determination a sample of 50 grams of the clay is made up with water to form a thin slip, deflocculated by the addition of small amounts of caustic soda or sodium oxalate according to the nature of the clay, and mechanically shaken for about one hour. The clay suspension is then passed through a series of small, conical sieves, telescoped together, ranging from 20 to 120 mesh. After washing and drying the residues on each sieve are weighed. The material which passed the 120 mesh sieve is reserved for further separation.

This is accomplished by means of the Schultz appartus, consisting principally of three conical cans, 2 in., 5 in. and 6 15/16 in. diameter respectively through which water is allowed to flow at a constant rate, 176 cc. per minute, see Fig. 1. It is readily seen that this gives the greatest velocity in the nar-

rowest and the lowest in the widest can. With the diameters and the volumes of water per unit time given, the largest particles settle in can No. 1, averaging about 0.0577 mm. in diameter, the next smaller in No. 2, averaging about 0.0354 mm., while in No. 3 the average size of the sediment approximates 0.0167 mm. Particles still finer, averaging about 0.005 mm. are carried off by the overflow. After the water flowing

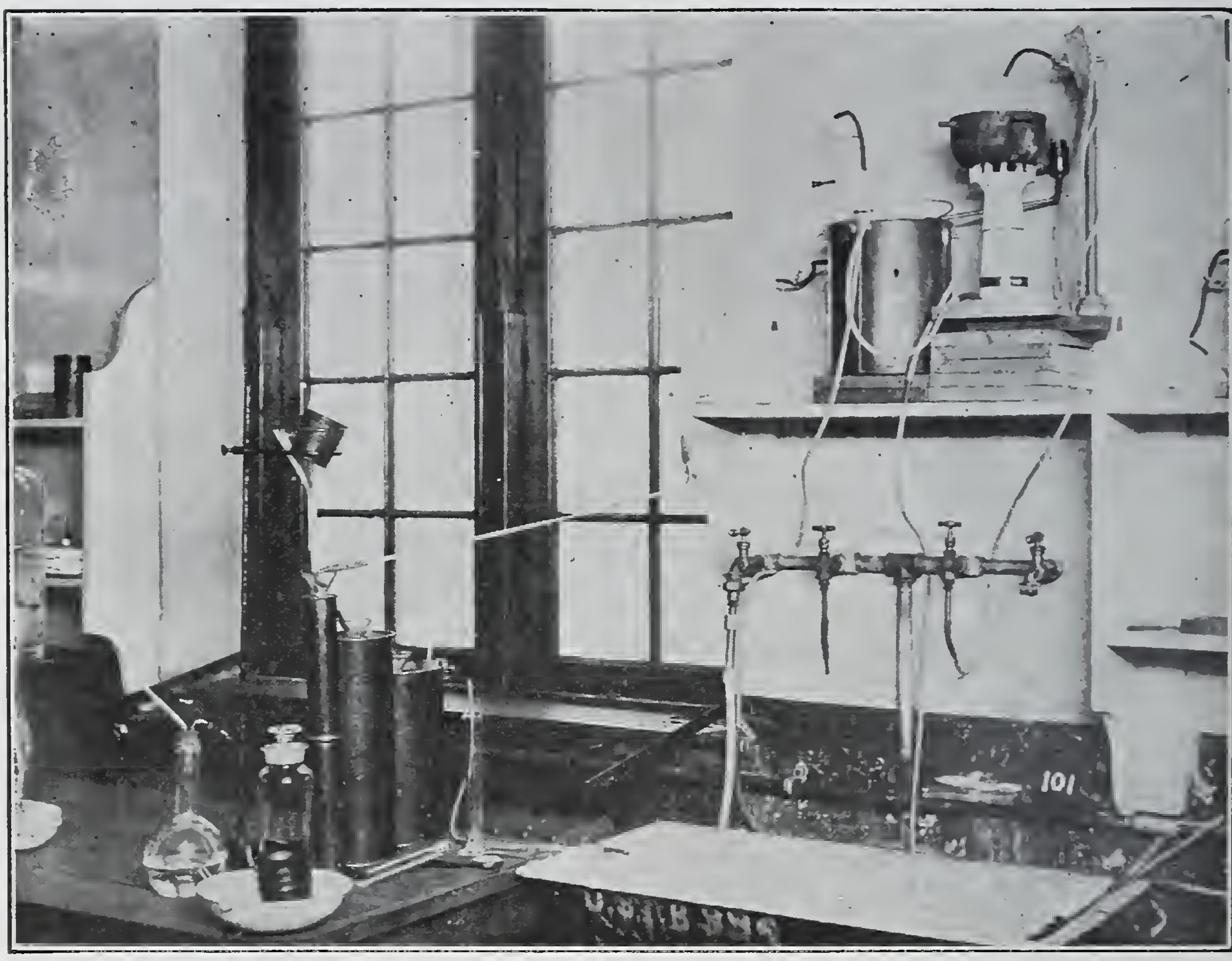

Fig. 1. The Schultz apparatus for the mechanical analysis of clays, etc.

from the third can appears to be clear the cans are emptied by syphoning down to the conical bottom. The water and clay in this part of the can is washed out, evaporated to dryness and weighed. The amount of the finest particles is obtained by difference. Though there are other methods and apparatus available for obtaining the mechanical analysis of clays the one discussed is one of the easiest to manipulate and its accuracy is sufficient for technical purposes.

Now in order to obtain a numerical value which expresses the fineness of a certain material the weights of the sediments found on the sieves, in the cans, and of the overflow material, expressed in percentages are divided by their average diameters and these values when added give the so-called Jackson-Purdy surface factor. This value evidently is the higher the finer the clay. The average diameters are compiled in the following table:

Meshes of Sieves per Inch.	Space Between Wires, mm.	Average Size of Particles Passing Sieve, mm.	Average Size of Particles Deposited in No. 1 Can, mm.	Average Size of Particles in No. 2 Can, mm.	Average Size of Particles in No. 3 Can, mm.	Average Size of Particles in Overflow. mm.
40	0.217	0.217	0.0577	0.0354	0.0167	0.0050
80	0.185	0.185				
100	0.150	0.150				
120	0.127	0.127				

Carrying the size factor into the question of plasticity and assuming that each grain of non-plastic matter is enveloped by colloidal material the volume of the latter required for unit weight of fine grained particles is evidently greater than for coarser grains, since the surface exposed by the former is greater than that by the latter.

The excess of colloidal matter remaining which gives to the mass as a whole its mobility and ability to flow under pressure is hence less with fine grained non-plastic particles and greater with coarser grains, and therefore Ashley concludes that plasticity is inversely proportional to the surface factor. Furthermore, practical experience also shows that the more plastic a material is the greater is its drying shrinkage. Combining these three relations: Colloidal matter present in the clay as determined by the dye treatment, its surface factor and its drying shrinkage we obtain the Ashley formula for expressing the plasticity value which is:

$$P = \frac{C\ S}{F}$$

where P=plasticity value
S=drying shrinkage
F=surface factor and
C=amount of relative colloids.

Drying Behavior. If we assume that clays are colloidal or sponge-like in structure in which the pores are filled with water, it is evident that on drying, the water gradually flows to the surface where it is evaporated. If the rate of flow is equal to the rate of evaporation, the clay will dry without difficulty. If, however, the rate of evaporation is greater than the rate of flow from the interior, then it is evident that a strain must be produced in the piece of ware, resulting finally in cracks or checks. The volume shrinkage up to a certain point is equal to the decrease in volume caused by the evaporation of water. In other words, the evaporation of one cubic inch of water will cause a shrinkage of one cubic inch of the clay. This is true up to the point when the particles, especially the non-plastic particles, come in contact with each other. At this stage the water films become isolated in separate pools between the grains of the clay and the water can no longer flow freely as it did before. At this point, therefore, shrinkage ceases, although there is still some more water left, the so-called pore water. With very plastic clays the drying problem is a very serious one, since it is difficult to evaporate the water from such materials without bringing about deformation or cracking. To overcome this difficulty the clay before drying proper begins, is subjected to the heating action of air at a fairly high temperature, saturated with water vapor. The clay becomes, under these conditions, uniformly heated throughout without evaporation and the viscosity of the water decreases sufficiently so as to insure as rapid a flow from the interior to the surface as possible. This system of drying may be carried out in any well designed tunnel or periodic dryer. Some clays are so exceedingly difficult to dry that no matter what precautions are taken they will invariably crack and warp when made up into heavier pieces. In such cases the usual remedy is the addition of non-plastic materials like sand or crushed, burnt clay (grog). Such a dilution opens up the clay structure and permits a more free circulation of the water. In addition, the shrinkage per unit volume of the resulting mixture is, of course, decreased, thus diminishing the strain im-

posed upon the clay structure. It is important in this connection that the non-plastic added be not too fine of grain since the desired effect is not obtained by the addition of fine matter. An interesting fact observed in the addition of granular material is that with smaller amounts the shrinkage increases at first until the condition of maximum density is reached after which the condension of volume on drying is rapidly diminished.

The most exact method of measuring shrinkage is by means of volume measurement using an apparatus of the type of the Seger volumeter. The relation between volume and linear shrinkage evidently corresponds to:

$$S_1 = \frac{\sqrt[3]{v_1} - \sqrt[3]{v_2}}{\sqrt[3]{v_1}} 100$$

where S_1=linear shrinkage in terms of the wet length
v_1=wet volume and
v_2=dry volume.

With some clays where for commercial reasons it is not practicable to add non-plastic materials to a difficultly drying clay it has been shown by the writer that preheating the clay as it comes from the bank in a rotary dryer to a temperature of about 450 deg. fahr., and then working it up in the usual way will reduce the drying shrinkage, and at the same time the drying loss sufficiently so as to cause the material to become workable.

Dehydration and Oxidation. When clays are burnt the temperature is raised very slowly so as to allow sufficient time for the escape of the hygroscopic water which clings to the clay with great tenacity. This stage is followed, at a red heat, or about 1200 deg. fahr., by the expulsion of the chemically combined water, an endothermic process of significance as regards the clay structure. At this temperature most clays lose their plasticity and at the same time become peculiarly sensitive to chemical agencies, being readily attacked by acids and alkalis, which does not hold true at higher temperatures.

At the same time during this period provision must be made to allow ample time and to admit sufficient free air to oxidize or burn out the organic matter, contained in all clays in greater or smaller amounts.* This is exceedingly important, especially with clays of dense structure, for if this is not done and the material is allowed to become denser as the burning proceeds, unburnt carbon remains which, during the last stages of firing, by partial oxidation, may give rise to gases the escape of which is prevented by the impervious outside shell of the piece. A bad case of this kind is shown in Fig. 2. It is evident that the spongy structure thus produced renders

Fig. 2. Specimen of bloated bricks due to improper oxidation.

the product practically worthless. Complete oxidation is recognized by the absence of a dark center on breaking open a brick or other clay ware.

Burning, Shrinkage and Porosity Changes. As the burning temperature increases and approaches the melting point of silver, about 1765 deg. fahr., the apparent clay volume again begins to shrink, a process which continues until vitrification has been completed.

* Edward Orton, Jr., Trans. Am. Ceramic Soc. 5, p 402.

This shrinkage is principally due to the closing up of the pores of the clay caused by the gradual fusing action of the mass when subjected to higher temperatures. Vitrification of clay means partial fusion carried sufficiently far to close up practically all the poral spaces. With some clays it takes place rapidly, as with calcareous materials; in others, it takes place slowly. The more gradually a clay vitrifies the safer it will stand up in the kiln without danger of deformation. Hence, of a number of clays which vitrify completely at the same temperature, that clay will be the most useful for general purposes which vitrifies at the lowest rate. This rate of vitrification, therefore, offers a means of discriminating between the various kinds of clay and if curves could be constructed in which we have plotted the progress of vitrification against the temperature, we would have a graphic representation of the burning behavior of a clay. The question now arises by what numerical data we can obtain curves of this character. These may be most easily deduced from the porosity of the clay determined at different temperatures. If thus we determine the porosity of the clay at five or six different temperatures up to the temperature of vitrification, we would obtain the desired curve by connecting these plotted points. The porosity evidently is the best practical measure of vitrication, since the progress of vitrification consists, as has been said above, in gradually filling up the pores of the clay until practically no more pores are observed. The porosity, of course, is quite easily determined by taking a suitable test piece burnt to the desired temperature, obtaining its weight when thoroughly dry, immersing it in water, in vacuo, weighing in the saturated condition and finally weighing it when suspended in water. The percentage porosity then becomes:

$$\%P = \left\{ \frac{W - D}{W - S} \right\} 100$$

where $\%P$=per cent porosity

W=wet weight of test piece

D=dry weight of test piece and

S=suspended weight of test piece.

This reasoning is of considerable practical value. For instance, in selecting a shale for the purpose of making paving bricks, it is desirable that the rate of vitrification or rate of decrease in porosity progress as gradually as possible.

Similarly, in selecting a fireclay it is evidently desirable that the clay possess as slow a rate of decrease in porosity as possible up to a temperature as high as possible, which would mean a temperature as high as 3200 or 3300 deg. fahr.

In order to determine the temperatures to be used in connection with such curves, either platinum-rhodium thermocouples or pyrometric cones are employed; the latter especially are used a great deal in practical work and are perhaps the best and simplest means of correlating the heat effect with the porosity.

Attention might be called briefly to the specific gravity changes shown by clays on burning. Specific gravity itself is a criterion of little value for practical clay testing, although it is of considerable significance from the theoretical standpoint owing to the fact that silicates on fusion decrease in density, i. e.; increase in volume. It is a fact, therefore, although not generally known that hard burnt clays actually increase in real volume, although the volume of the clay body is diminished by the filling up of the pore spaces.

If vitrification is carried beyond a certain point, it is found that the porosity again increases. This is explained by the fact that numerous gas bubbles are evolved from the clay during the last stages of vitrification which may be absorbed air or carbon dioxide, sulphur dioxide, oxygen or other gases. Owing to the viscous state of the highly heated clay these gases cannot escape and hence appear in the form of "blebs," and may cause an increase in the exterior volume of the product. It is evident that such a structure is detrimental as regards strength, resistance to abrasion or weather resisting qualities and hence overburning of the clay must be carefully avoided. Some clays are more apt to give trouble in this respect than others since in certain clays the formation of gas

bubbles may be quite prominent even during the first stages of vitrification. Careful and intelligent burning, especially careful oxidation, may do much to overcome this difficulty.

Fusion. When a clay is carried beyond the practical point of vitrification through the stage of viscous vitrification we finally reach the point at which it becomes a semi-fluid mass. Clays, being substances of complex structure and high internal friction, do not possess a definite melting point such as is shown by metals and minerals. The transition from vitrification to fusion is a gradual one. In speaking of the melting point of clay, therefore, we merely mean that point at which by means of some special device a certain deformation takes place. In practical work we generally employ a shape corresponding to that of a tetrahedron and we consider that the so-called fusion point has been reached when the test piece bends sufficiently so that its apex touches the plate upon which the cone has been placed. It is evident that though the clay has softened it is far from being fused.

The temperature of softening or fusion differs widely for different clays, many of the red burning clays become semi-fluid at temperatures as low as 2000 deg. fahr., while the most refractory clays reach a temperature as high as 3350 deg. fahr. The softening point is usually determined in a small Deville furnace heated by means of gas carbon and compressed air or by means of electric muffle furnaces. A good fireclay ought to resist a temperature of 3200 deg. fahr. before it softens when shaped into a cone about one inch high. The temperature of ultimate fusion is a complex function of a good many factors, such as the chemical composition, size of grain, mineral character, manner of shaping, time and rate of heating, etc. Usually the chemical composition is the most important factor. The most infusible clay is that corresponding to pure kaolin, which has the following composition: Silica 47 per cent, alumina 39 per cent, chemical water 14 per cent. Any considerable increase in silica or any other constituent excepting alumina will cause a lowering of the melting point. Thus, contrary to popular opinion, any increase in silica beyond that

demanded by the kaolin composition means a decrease in the refractory nature of the clay. Naturally, of course, the effect of iron oxide, lime, soda, potash and magnesia is to lower the refractoriness of the clay most decidedly.

Strictly speaking, the fusion of clays, depending on their chemical composition begins at quite low temperatures, probably as low as 1800 deg. fahr. since vitrification must be considered as a partial fusing process. It seems that even at low temperatures the constituents of clays combine and mutually dissolve each other by selective action as much as possible to the extent of forming a combination which is fusible at these low heats. While in highly refractory clays the amount of fluxes making such easily fusible combinations possible is small, this is not true of the low grade materials where there is an abundance of alkalis, ferric oxide, lime and magnesia. As the temperature rises these easily fusible combinations vary in composition becoming increasingly more refractory but at the same time their amount becomes larger and larger until the entire clay body softens sufficiently to fill its pore spaces and finally the whole mass becomes more or less viscous. At the final stage, of course, the ultimate refractoriness of the clay as a whole is reached. This explains why some clays become denser at lower temperatures than others although their ultimate refractoriness may be equally great. These facts are of the utmost importance in connection with the resistance of fire bricks and blocks to load conditions at higher temperatures as will be shown later on.

Strength of the Burned Product. The gain in the crushing strength of clay products with increasing burning temperature is due to two reasons, the hardening of the clay body itself with the progress of vitrification and incipient infusion, and the decrease in pore space. The strength is lowest at the dehydration temperature since at this point both the intrinsic strength is at its minimum and the porosity is greatest. The resistance to compression increases steadily, however, as the porosity decreases, practically in a straight line until vitrification becomes very noticeable. At this point most

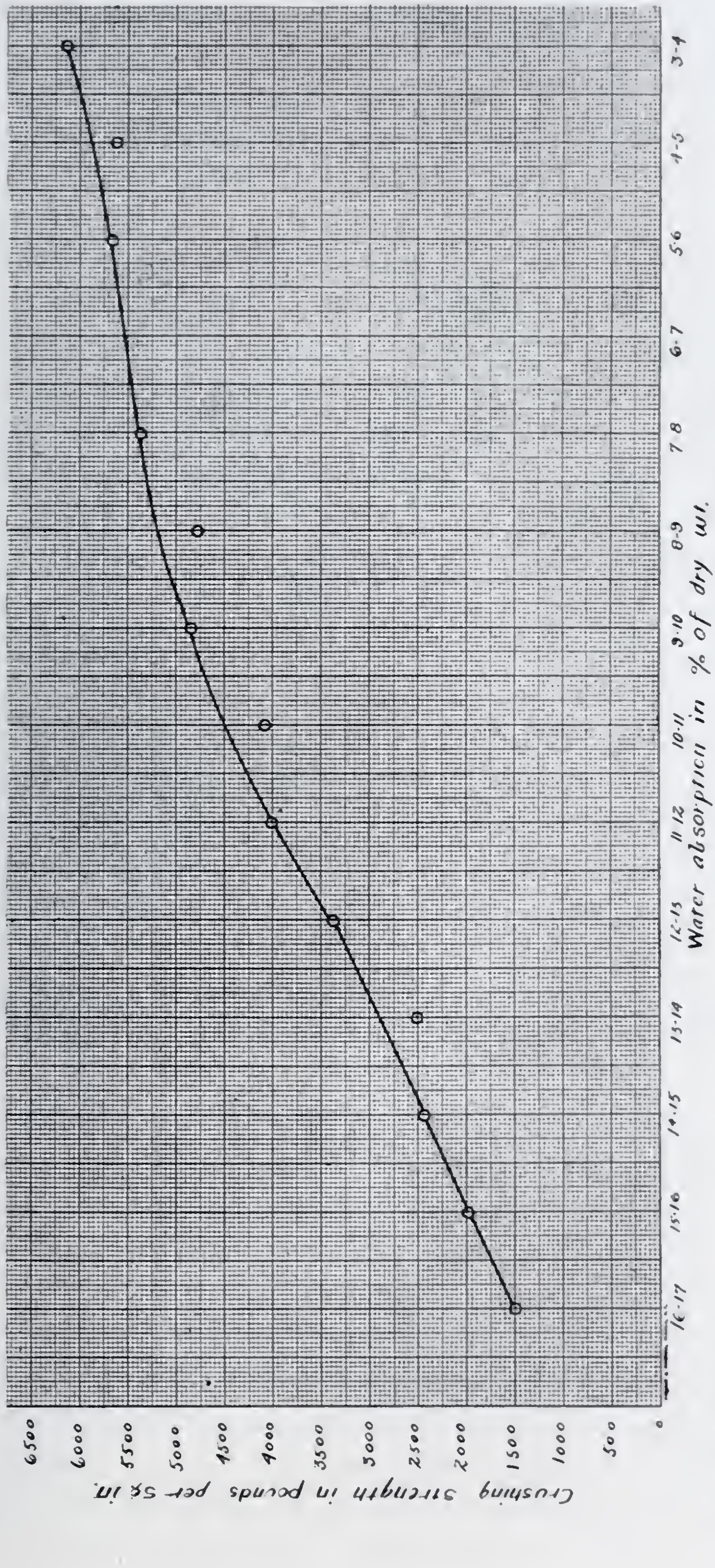

Fig. 3. Curve showing relation between absorption and crushing strength of bricks made of the same clay and under the same conditions, but burnt at different temperatures.

clays show rapidly increasing strength, though some appear to lag at this stage. The porosity-strength curve then reaches a maximum point beyond which the strength decreases and the porosity again increases. It is evident that this is due to the overburning of the clay and the development of a vesicular structure.

In Fig. 3 a curve is shown which illustrates the growth of the strength of a certain make of bricks as compared with the porosity measured by the absorption of water, which is expressed in terms of the dry weight of the bricks. With this clay a lag is observed after an absorption of between seven and eight per cent of water. For the material tested it seems therefore that this point would indicate the best practical condition for building brick. In this curve the maximum point is not reached, since the overburning stage is absent.

Referring to the resistance of clay to abrasion, a curve indicating the relation between porosity and toughness would probably show a relation similar to that existing between crushing strength and porosity; though from the results of Orton it would appear that the point of maximum toughness is somewhat below that of complete vitrification. As with the compression strength curve, the overburning would bring about a similar result. The conditions of greatest toughness require that the clay body be not too glassy in structure, which means that the vitrification of the clay must not be complete.

Resistance to Freezing. Well burnt clay products made from clay thoroughly pugged and tempered are practically unaffected by ordinary freezing. However, a very fine grained clay which has not been burnt hard, that is, with a high porosity, will suffer more from frost than clay of the same total porosity but consisting of larger pores. The latter will permit of the escape of the ice needles which are formed when the water contained in the brick freezes, while the fine pored material cannot discharge the ice from its superficial capillaries and consequently must bear the strain due to the expansion of the water on freezing. It is evident, however, that

the farther a clay is carried towards vitrification the more it will resist the destructive effect of freezing, provided, as has been said, it has been well prepared. Poorly prepared and pugged clay, or clay material shaped under bad conditions, that is, by machines producing a laminated structure, will suffer by the freezing of the water between the planes of laminations. A brick may also be subjected to great strain on freezing when covered with enamels or glazes, since in this way any water absorbed cannot find a ready escape. It is always the best policy in exposed work to use clay products as near the point of vitrification as possible, since at this stage practically no water, if any, is absorbed; and hence no damage can be done by freezing.

COLOR. The appearance of the raw clay is no criterion whatever as to the color of the burnt product. The colors of clays vary widely from the white of the kaolin to the dark red, or black, of the red burning clays. The main coloring constituent of clays is iron oxide and according to the amount present it gives colors ranging from buff to red.

The presence of lime, however, may counteract the red of the iron oxide and change it to buff. Again the color of clays is affected greatly according to whether oxidizing or reducing conditions prevail during the burning. Oxidizing firing invariably tends to produce the light colors, while reducing firing gives rise to the dark shades.

TESTING OF CLAYS FOR SPECIFIC PURPOSES

COMMON BRICKS. In the testing of clays for the manufacture of common bricks, it is evident that the main considerations involved are those relating to the cheapness with which a good marketable product can be manufactured. We need know only that the bricks can be molded rapidly by means of the stiff, soft mud, or dry press, process. It must have sufficient plasticity to be worked by the stiff or the soft clay process, it must dry easily; it must burn to a fair hardness and must contain no injurious substances like lime in excessive amounts.

FACE BRICK AND TERRA COTTA. Clays for this purpose in addition to drying and burning safely must possess a clean color and must be free from soluble salts causing efflorescene or white-washing. The porosity curve should be a gradual one, so as to insure safe burning and a low kiln loss.

FIREPROOFING. Clays suited for this purpose should be of the class of the No. 2 fire clays with a softening point of not lower than 2900 deg. fahr. At the same time the content of

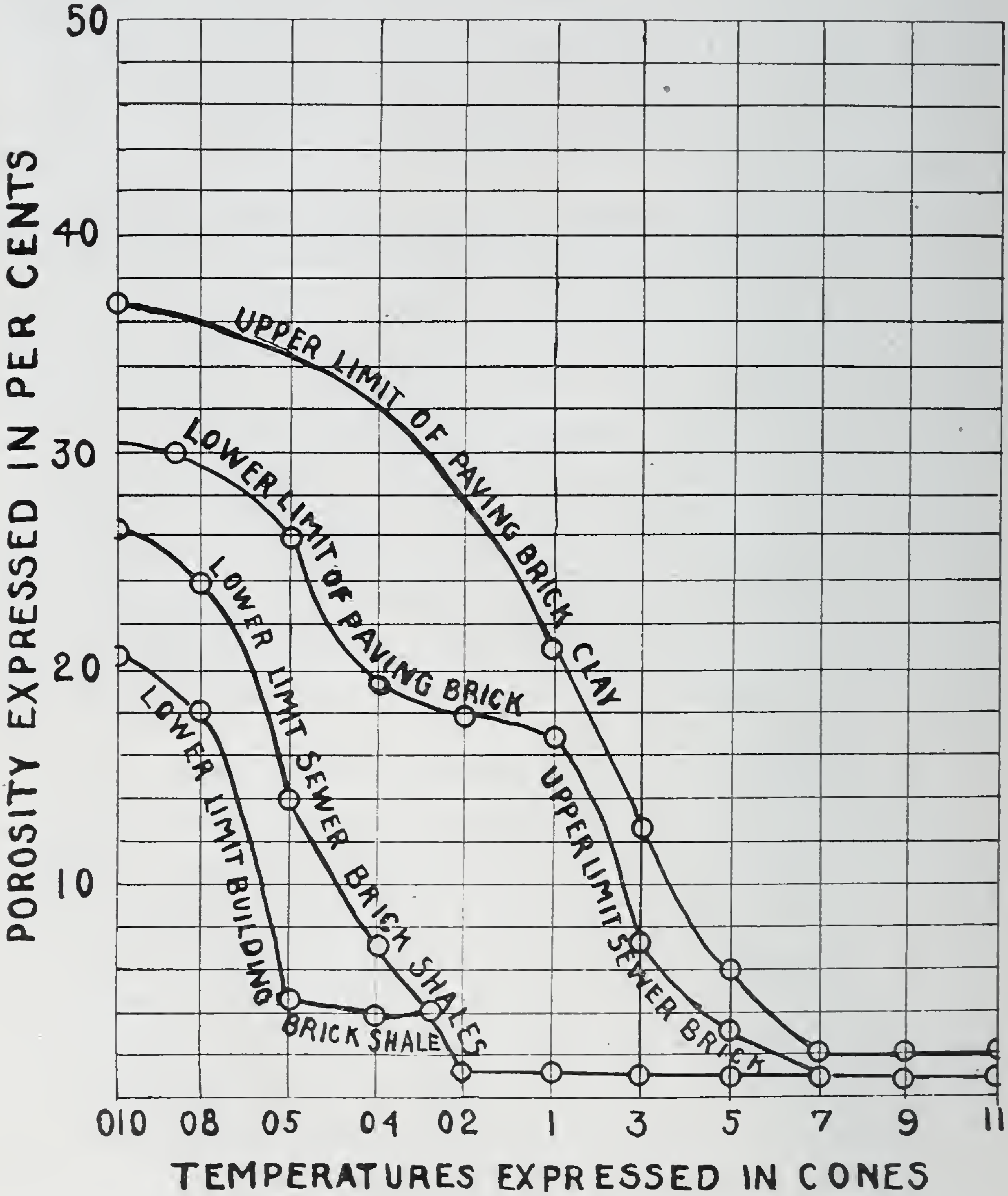

Fig. 4. Curves showing the vitrification behavior according to Purdy.

fluxes should be low enough so that no indications of deformation are noted under fair loads at a temperature of about 2200 deg. fahr. Silicious clays are to be preferred for this purpose since they hold up better under fire conditions under the loads to which these products may be subjected. The ultimate melting or softening point is of less importance in this respect than the ability to carry loads at a fairly high temperature, though required loads are but slight and usually do not exceed 5 to 10 pounds per sq. in.

PAVING BRICK. In order to be suitable for paving brick a clay should possess a shale structure with sufficient plasticity to work well in the auger machine. As a rule surface clays of any kind are unsuited for this purpose. Its chemical composition should be such that it vitrifies at a sufficiently slow rate to a dense, hard yet tough body which shows no excessively glassy structure. In a very interesting investigation Purdy* has shown that the rate of vitrification is an excellent means of indicating the character of paving brick shales, i. e. the slower the porosity decreases for unit rise in temperature the better suited it is for the purpose. This is illustrated in Fig. 4 where the permissible limits are indicated by the vitrification curves and where the paving brick shales are differentiated from the building brick materials.

FIRE CLAYS. The so-called No. 1 fire clays are usually tested primarily for refractoriness. This is done by placing conical specimens of the material to be tested upon a refractory base together with a number of standard pyrometric cones. After a preliminary heating to redness the base and its cones are placed into a Deville or similar furnace and subjected to a temperature sufficiently high to soften or fuse the clay speciments. After cooling the furnace and removing the base the condition of the clay is compared with that of the test cones, the number of the cone which has softened to the same extent as the clay specimen being noted. It may be necessary to repeat the test with higher or lower pyrometric cones as the case may demand.

* Trans. Am. Ceramic Soc., vol. 9.

In the laboratory of the Clay Products Section, an electrical carbon resistance furnace, Fig. 5, is used for this purpose in which the condition of the cones may be observed during the test and the temperature estimated by means of the optical

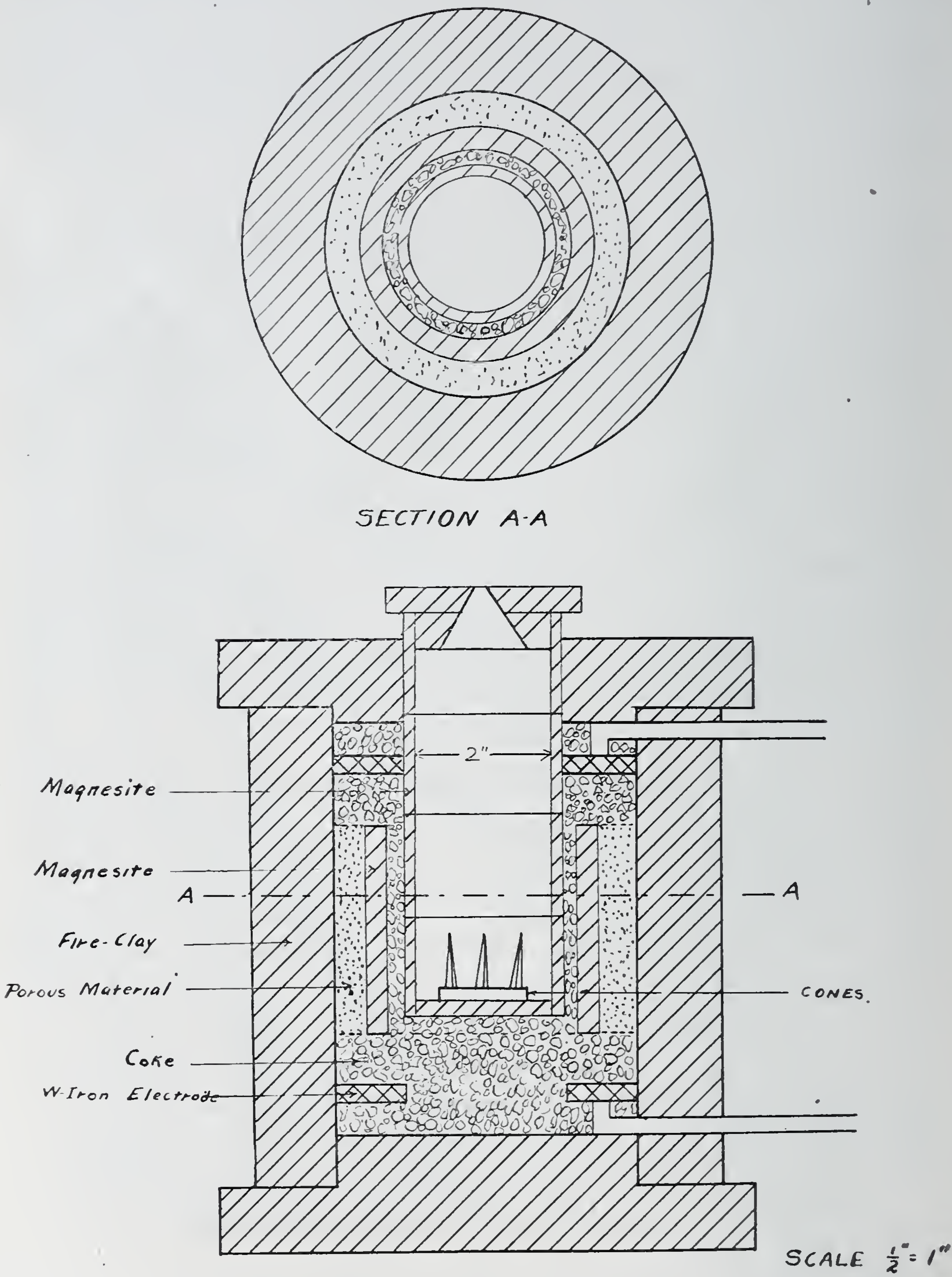

Fig. 5. Electrical carbon resistance furnace for testing fire clays.

pyrometer. The specimens are here placed in a magnesite muffle, made up in sections and coated on the inside with a thin layer of alumina. The resistance material is electrode carbon. A No. 1 fire clay should not soften below cone 30. Since fire clay goods are usually compounded of an exceedingly refractory, but slightly plastic "flint" and a much less refractory but plastic clay, it is important to consider the refractoriness of the mixture which may be greatly below that of the flint clay alone. In most cases, where either great refractori-

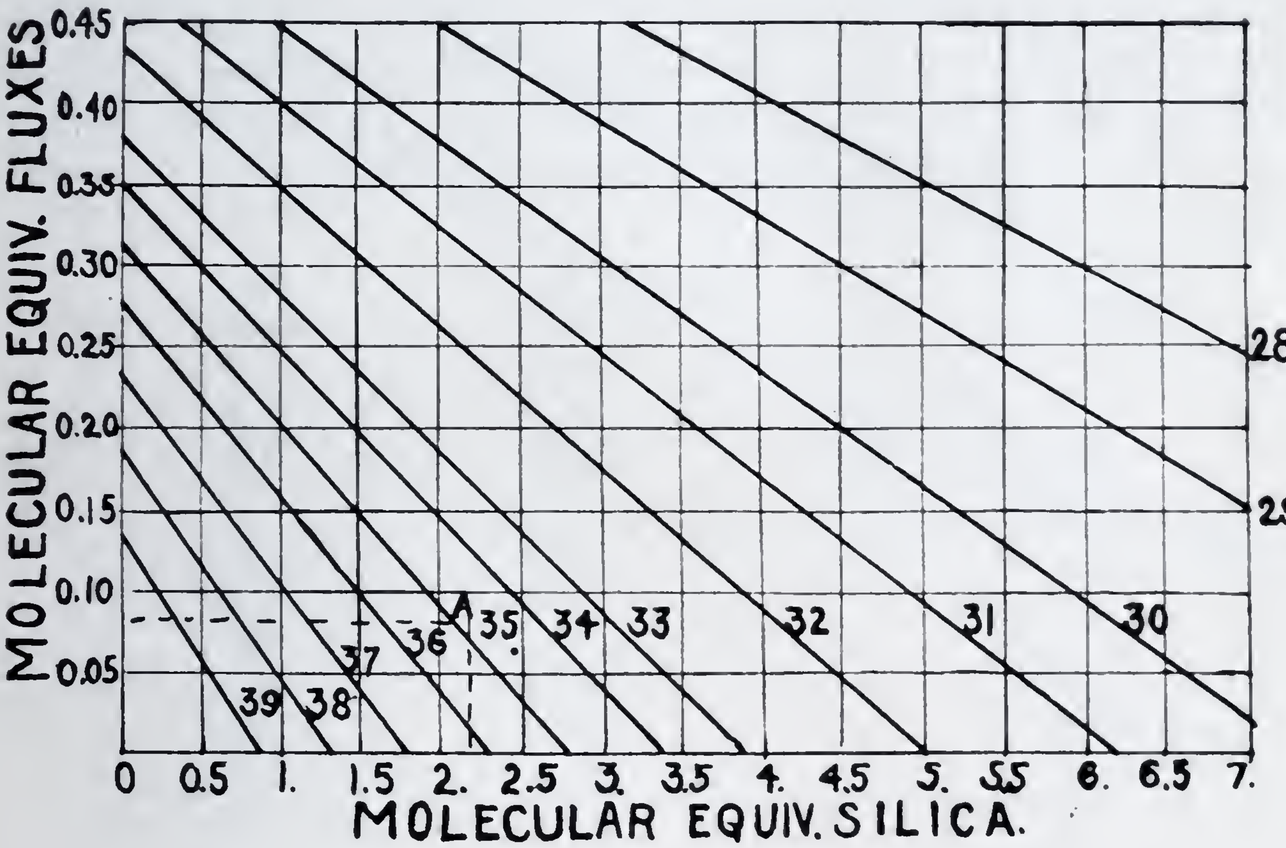

Fig. 6. The Ludwig diagram showing relation between the chemical composition and the refractoriness of fire clays.

ness or ability to carry loads at high temperatures is required, the amount of plastic clay used should be as low as possible. It may even be necessary to improve the refractory quality of the plastic bond clay by grinding it intimately with some of the flint clay, though this is not practiced by any plant as far as the writer knows.

As to the chemical composition of No. 1 fire clays, it may be said that they should approach the composition, 39 per cent alumina, 47 per cent silica and 14 per cent chemical water. An

increase in silica at once lowers the refractoriness. While a very small addition of alumina may act in the same direction, any appreciable addition of this substance will raise the refractory quality. The so-called fluxes, potash, soda, lime and magnesia are very potent in reducing the refractoriness of fire clays, as may be seen from Fig. 6 which represents the diagram of Ludwig.* By calculating the equivalent molecular amounts of silica and the total fluxes (alumina being made to be equal to one molecular equivalent in all cases) it is readily seen that the refractoriness decreases with an increase in silica as well as with the increase of fluxes. The numbers 39, 38, etc. indicate the numbers of pyrometric cones the softening points of which correspond to the following approximate temperatures:

No. Cone.	Deg. cent.	Deg. Fahr.
28	1690	3100
29	1710	3140
30	1730	3170
31	1750	3210
32	1770	3250
33	1790	3280
34	1810	3320
35	1830	3350
36	1850	3390
37	......	......
38	......	......
39	......	......

In considering the value of a clay for refractory purposes the use of the product to be manufactured from it must be kept in mind. In many fire clay goods it is not necessary that the ultimate refractoriness be very high, sometimes their resistance to abrasion at moderate temperatures is most essential and again they may be required to carry loads at temperatures which are very much below those of the ultimate softening. Hence it may frequently be the case that a clay of comparatively low refractoriness, due for instance to its high content of silica, may prove very desirable in gas retort benches, arches and similar construction work.

* Sprechsaal, 1904, No. 14.

The fire clays according to their rate of vitrification have been classified by Purdy as No. 1, No. 2 and No. 3 clays, the first showing the lowest average drop in porosity per cone, the last the highest decrease. In Fig. 7, the Purdy diagram* is reproduced thus showing the basis underlying his classification.

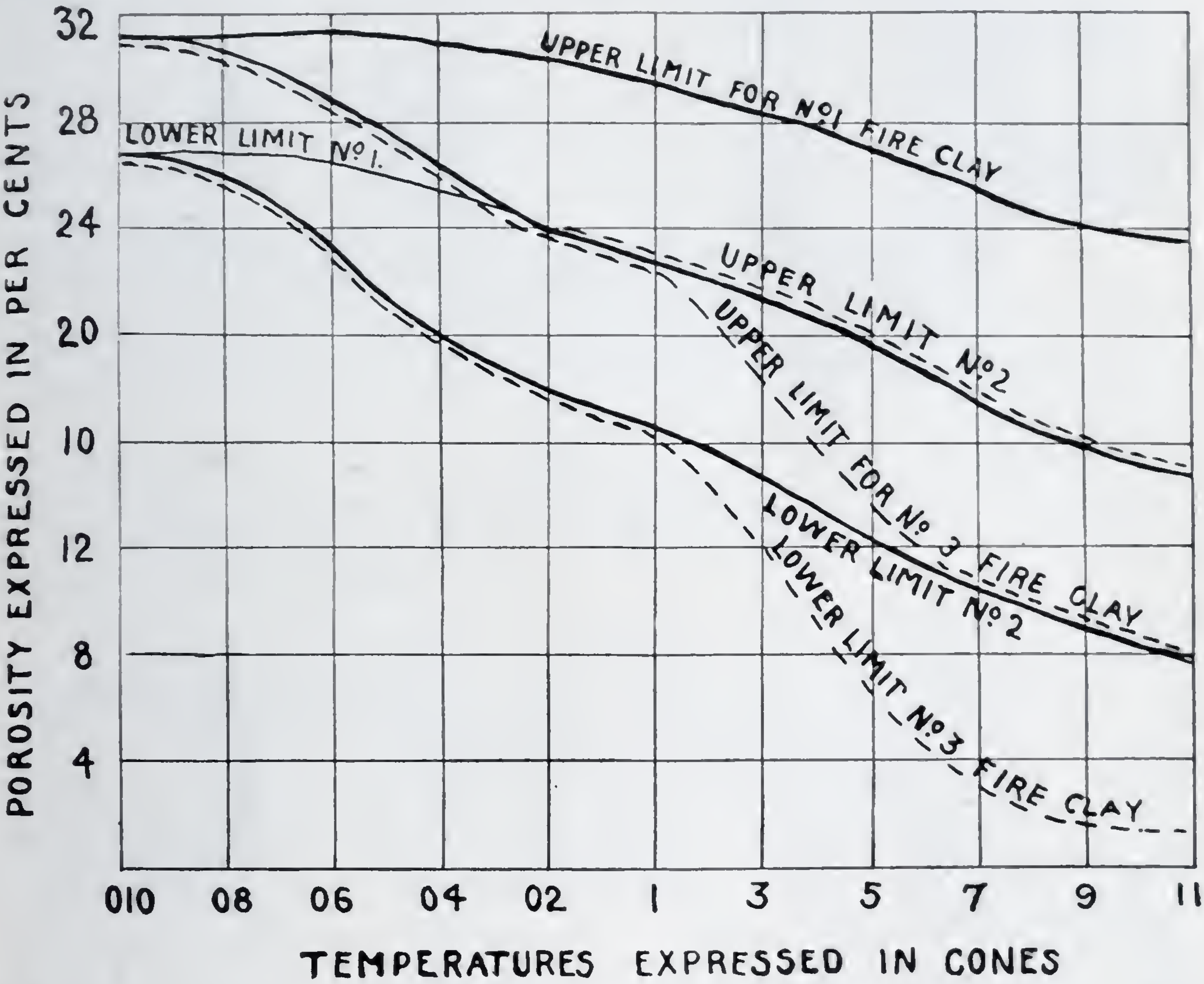

Fig. 7. Curves showing relation between three grades of Illinois fire clays according to their rates of vitrification, according to Purdy.

Pottery Clays. We must distinguish between two kinds of clay which are needed in this class of work: First, a clay as white as possible; second, a clay as plastic as possible. Since these two factors are never present in the same material, we are compelled to use both kinds of clay, endeavoring to bring in as much as we can of the white burning clay (kaolin) and using as little as possible of the plastic clay, (ball clay), owing to the fact that in-

* Illinois Geol. Survey, Bull. 9, p. 271.

variably the most plastic clays burn to a yellowish or buff color which is not desired. The ideal clay for pottery making

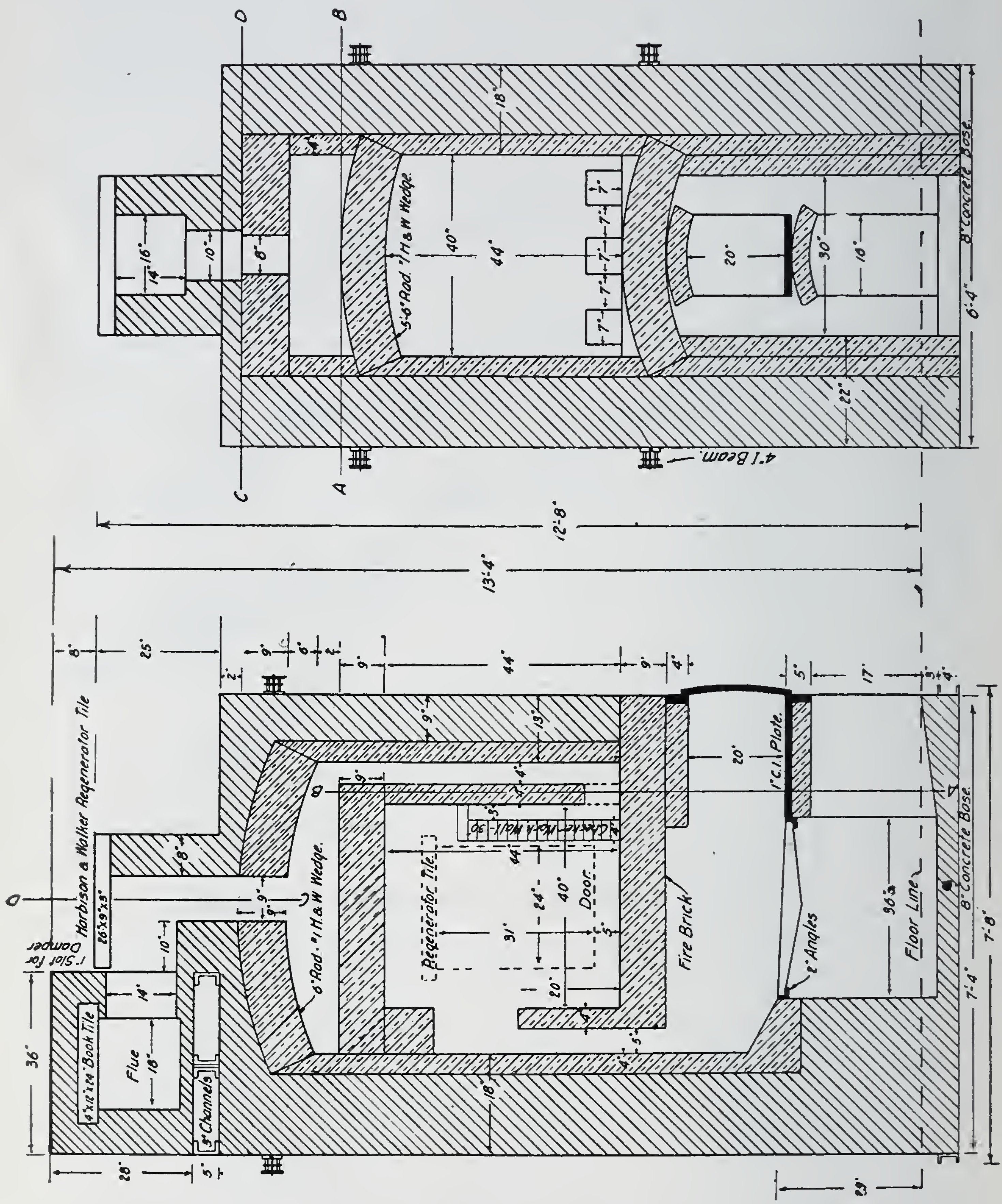

Fig. 8. Test Kiln of the U. S. Geological Survey Clay Laboratories.

would be an exceedingly white burning plastic clay, but so far it has not been found. In testing pottery clays we usually determine the color by firing as well as the drying and the

burning shrinkage. The working behavior of the clays as well as of their mixtures with feldspar and flint is found by practical tests on the jigger or the throwing wheel.

Test Kilns. The kilns employed for the burning of the various clay products in the Clay Products Laboratories are of the down draft type and the design adopted has been exceedingly satisfactory as regards uniformity of temperature. Either coal or gas may be used as fuel. It is desirable that the draft be regulated by means of a sentitive gauge so as to insure uniform conditions. A temperature of cone 14 may easily be reached. In Fig. 8 the construction of this kiln is shown.

THE TESTING OF CLAY PRODUCTS

Owing to the fact that all specifications for clay products are still in the embryonic state, no definite requirements can as yet be laid down. No official specifications have as yet been published nor will it be possible to do so for some time. In the following brief outline it is intended simply to indicate the method of procedure.

Building Bricks. In testing bricks the tests commonly employed are the absorption, crushing, transverse and freezing tests. The absorption test is carried on by immersing the brick in water, flatwise, to a depth of one inch in a covered receptacle. The brick, of course, must be dry and is weighed before and after immersion. The water absorption is usually expressed in terms of the dry weight of the brick, though it would be more accurate to define it in terms of volume. A good building brick should not absorb more than 15 per cent of its dry weight of water.

The crushing strength test, unfortunately, is usually carried out by subjecting the whole or a half brick to pressure, when bedded flatwise. This gives extremely erratic results with great possible errors. It is far more advisable to test a half-brick, bedded in plaster on edge, since in this way a far sharper failing point may be observed, while in the flat condition this point may be far exceeded. In some European testing laboratories it is customary to use two brick halves,

cemented together by means of Portland cement mortar. This gives excellent results since the shape of a cube is approached quite closely but the method has not yet found favor in American practice. A good building brick should show a compression strength of not less than 2500 lb. per sq. in., tested on edge.

In cutting the bricks, sawing would, of course, be most desirable; but owing to the usual lack of facilities and the time consumed it is not practiced in this country. In many laboratories the transverse test precedes the crushing test in which case the latter is carried on with the pieces resulting from the former. It has been found, however, that careful cutting with a sharp chisel does not seem to injure well made and burnt bricks, though it may be detrimental to specimens showing weak, or laminated, structure.

The modulus of rupture of good building bricks, placed flatwise upon rounded knife edges, seven inches apart, should average about 400.

In the freezing test the brick is thoroughly saturated with water and subjected to a temperature of not more than 15 deg. fahr. for at least five hours, care being taken to immerse the specimen in ice cold water just before freezing and to support the bricks by a wire frame or by suspension so as to get maximum contact of the atmosphere in the refrigerator with the surface of the bricks. After each freezing the bricks are removed and placed in water at a temperature of not less than 150 deg. fahr. for one hour. The test is repeated ten times. Good building brick should show no serious cracking or spalling after this treatment.

Paving Brick. Such bricks are subjected to the National Brick Manufacturers' standard rattler test in which the abrasion loss should not exceed 17 per cent of the weight of the brick.

Fire Brick. The tests made are usually the refractory test, chemical analysis, and the determination of the porosity before and after reburning at cone 12. According to the use

to which the bricks are to be put, other supplementary tests may be made such as the resistance to abrasion (for the top of blast furnace linings), the ability to carry loads at ordinary furnace temperatures, about 2400 deg. fahr., (for gas retort benches, arches, etc.), and the heat conductivity as well as the specific heat (for blast stove work, regenerators, recuperators, etc.), the resistance to sudden temperature changes, etc.

A good fire brick should withstand a temperature of 3100 deg. fahr., cone 30, without showing any signs of fusion. Its chemical composition should approach as closely to 54.6 per cent of silica and 45.4 per cent of alumina as possible, though a higher amount of alumina is desirable. In reburning a fire brick to cone 12 (about 2500 deg fahr.) a good product should show a decrease of not more than 20 per cent of the original porosity, as measured by the water absorption. A larger decrease in porosity is undesirable since the external volume change, coincident with the reduced porosity, is detrimental to the brick work. At the same time this would insure the use of harder burnt bricks.

For the top of blast furnace linings it is evident that the greater the resistance of the brick to abrasion, as measured by a rattler test, the more suitable they would be for this purpose.

As regards the resistance to load conditions it has been found in the clay products laboratory that a good fire brick should withstand a temperature of 2370 deg. fahr. under a load of 75 lb. per sq. in., the brick being placed on end, without deformation or cracking. The duration of this test is five hours, the temperature being brought up in four hours and maintained for one hour. In Fig. 9, three tests are illustrated showing two failures and one satisfactory condition.

The heat conductivity evidently becomes a prominent factor in metallurgical work: in some cases it must be as low as possible, where heat is to be retained, and in others as high

as practicable where heat is to be transmitted. The principal control of this feature is in the porosity since it has been shown by recent work that the more porous a clay body is, i. e., the greater the volume of the air cells, the lower will be the resulting conductivity, and vice versa. The porosity on the other hand is regulated by the method of manufacture, soft mud, stiff mud and dry press, the degree of burning, or the addition of organic material like saw-dust, which burns out and leaves a very porous structure.

This subject is of vital importance to the metallurgical engineer and it is surprising that these facts are not made

Fig. 9. The behavior of fire brick under load conditions of 75 lb. per sq. in. and at 2370 deg. fahr. Speciments 27 and 9 have failed and 19 has passed the test.

use of more largely in practical work. In many cases air spaces are depended on for heat insulation of furnaces, although it has been established that at the temperatures in question the heat loss due to radiation through the air is an exceedingly important factor. There is no doubt but that the use of porous insulating material either loose or in the form of open grained bricks ought to be far more general than it is in order that the losses due to conduction as well as radiation may be reduced to the minimum. One frequently observes furnace walls built up of dense bricks which conduct away the heat at a rapid rate.

Wologdine found the conductivity of fire clay bodies to vary between 1.07 and 1.81 kg. calories per hour, per square

meter and thickness of one meter for a temperature difference of 1 deg. cent. This investigator found that the conductivity is, roughly speaking, inversely proportional to the porosity.

The specific heat of fire brick increases with the temperature. Howe and Harrington* have found that it rises according to the relation $0.215 + 0.00006\, t$, the temperature, t, being expressed in degrees centigrade.

In order to determine the resistance of fire bricks to sudden heating and cooling some arbitrary test like heating the specimens to redness and cooling them rapidly in air, or by quenching in water, is sometimes employed, any cracking or checking being noted.

In using fire bricks and other refractory products, the engineer should make himself thoroughly familiar with the requirements for any specific purpose. Only too frequently the failure of such products is due to a lack of understanding on the part of the user. It is not uncommon to find in use low grade products purchased at a low price where the best material should have been used, and again high grade bricks where a No. 2 or even No. 3 fire brick would give just as good or even better service. This subject is a large one and justice cannot be done to it in this brief space.

Fire Proofing. Only very general mention can be made of certain broad requirements since the data at hand is very meager indeed. Products of this kind used for the protection of steel beams and girders should be manufactured from a No. 2 fire clay, preferably a silicious one, and the ultimate softening point should not be below 2900 deg. fahr. The porosity should be as high as possible consistent with sufficient strength. The clay should possess an average compression strength of about 2000 lbs. per sq. in., when made up in the shape of a four inch cube. From this the desired porosity can be deduced.

Any addition of organic matter like saw-dust in the process of manufacture for the purpose of increasing the por-

* Prac. Eng. 34 815.

osity is desirable, provided the burning has been done with care.

A practical test would be similar to the one employed at the National Underwriters' laboratory where a panel of material is heated up uniformly on one side to 1700 deg. fahr., and then cooled with a stream of water under pressure.

Sewer Pipe, Drain Tiles, Hollow Blocks and Conduits. No satisfactory specifications exist in regard to these materials, although the International Society for Testing Materials has made an attempt to formulate certain requirements. Inspection of the product as to ring, appearance of glaze, presence of laminations, etc., is about as satisfactory as anything that can be done.

Terra Cotta, Roofing Tiles, Etc. Owing to the many shapes in which this kind of product is manufactured, it is, of course, difficult to provide for specific tests. However, it should be required not to exceed a certain water absorption and should resist the freezing test without any indications of cracking. Where impervious ware is specified a modification of the permeability test might be employed in which a wide glass tube is cemented on to the surface and filled with water. The taking up of water by the surface is thus readily observed by the lowering of the water level.

Glazed terra cotta should be free from crazing and shivering and the glaze should not be attacked by fumes of hydrochloric acid or by treatment with a 1:10 solution of this acid.

With regard to the testing of glazed wall tiles, etc., too little is known concerning the effect of temperature changes, the stresses caused by the cement mortar, due to the difference in the coefficient of expansion, and to the soluble salts taken up by the mortar, to make specific requirements. What has been said in regard to terra cotta however should apply also here.

Electrical Porcelain. This material is usually inspected only when used for high tension transmission lines. The pettycoats of the insulators are generally tested for punc-

ture before being cemented. The data on this subject is quite meager. The results obtained in a series of tests with which the writer is familiar showed a maximum puncture voltage of 18 000 and a minimum of 10 000 volts per mm. thickness. It is important in connection with this class of ware that vitrification be practically complete so that the absorption is virtually nil, but that at the same time the body be free from any excessive "bleb" structure which is very detrimental. At the same time no mechanical flaws must be present due to faulty jiggering or defective plaster molds. The glaze must be perfect as far as covering the body is concerned and no signs of crazing or shivering can be tolerated.

POTTERY. The testing of pottery, a subject which is not covered by the work of the clay products laboratories at present, naturally cannot be treated from the strictly technical standpoint but as far as service is concerned the hardness of the glaze, the impermeability and toughness of the body are criteria which determine its quality from the practical standpoint. The expert is able to tell much of the character of the ware by inspection and a simple test like scratching with a steel point. It is not generally recognized however that there are differences in toughness which explain the longer and shorter life of certain makes. This factor could be arrived at by means of more exact tests following the line of a modified rattler test.

PROBLEMS UNDER INVESTIGATION IN THE CLAY PRODUCTS LABORATORIES.

The writer will conclude with a short summary of the problems which have been attacked and in part or wholly completed.

A. Preliminary drying treatment of clays. Owing to the fact that many clays, especially those of some western states, are so excessively plastic that it is almost impossible to dry them without great loss, it was thought advisable to study some of the methods available for treating these materials so that they might become useful for brick making and

other purposes. The simple plan of preheating these clays at about 400 to 450 deg. fahr. before putting them through the

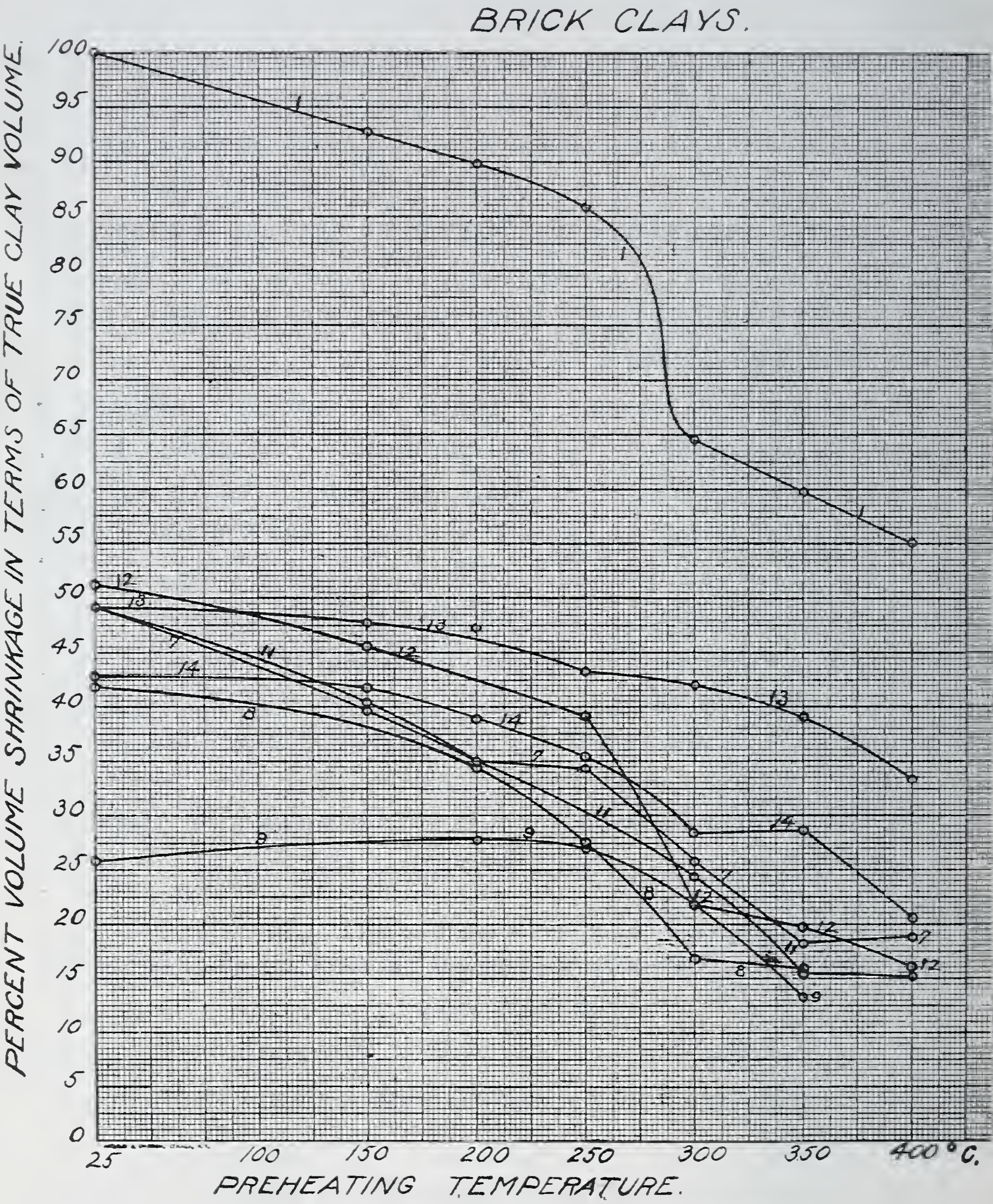

Fig. 10. Curves showing effect of preheating at different temperatures upon the volume shrinkage of clays.

preparing and molding machines was found to work successfully with a number of clays. The drying shrinkage was reduced and the loss in drying eliminated. In Fig. 10 the drying

shrinkages in terms of the true clay volume after heating to a number of temperatures are shown.

B. The amount and character of the colloidal matter present in clays offers an exceedingly interesting and important field of study to which the clay products laboratories have given considerable attention as far as the technical control of clays during manufacture is concerned. One bulletin has been published on this subject and another is in preparation.

C. A study is being made of the inherent toughness of several classes of clays as regards their use for the manufacture of paving brick. It is hoped that satisfactory testing methods may be evolved and that some light will be thrown upon this rather obscure topic.

D. The testing of fire bricks both as to ultimate refractoriness and their ability to carry moderate loads at furnace temperatures is the subject of another study which has been practically concluded and which has produced some very interesting results.

E. Another topic under investigation is the study of the relations existing between the modulus of elasticity, the ultimate crushing strength and the true porosity of different classes of clays burnt at different temperatures and made under uniform conditions.

F. The effect of soluble salts upon burnt clay as to their destructive action and production of efflorescence. This work is being done at the request of the Reclamation Service.

As has been said above, the main part of the work consists in making tests for the various Government Departments such as the Isthmian Canal Commission, the Supervising Architect, etc. In connection with the erection of many federal buildings it has been possible to make numerous tests of considerable practical value.

No claim is made that this review is complete, but it is hoped that it will show the extent of the field covered by a clay products laboratory such as has been described.

DISCUSSION

Mr. N. S. Sprague: I am sure this society feels greatly indebted to the speaker for this very instructive and interesting paper. It is of special interest to me on account of having been confronted by some of the points which the author has presented.

In this city there seems to be an increasing demand for vitrified repressed paving brick. It is coming into use more generally, replacing particularly block stone and asphalt pavements for the alleys and residence streets where the traffic is light. During the last year the city has spent in the neighborhood of $165 000.00 for brick paving alone which emphasizes the importance of a knowledge of this material..

Specifications for paving brick were heretofore rather loosely drawn and contained no particular requirements for abrasion, absorption or compression tests, which resulted in the introduction into many pavements of bricks of inferior grades. The merits of the different kinds of bricks which were submitted by contractors were judged mainly from their appearance.

A series of physical tests of a number of bricks of different manufacture were made which showed that some of these materials which had been used had a loss of 33 percent in the abrasion test and as high as five and six percent in the absorption test and in the crushing strength the figures ran as low as 4500 lb. per sq. in. This condition of affairs demanded immediate action and the matter was investigated. As the speaker pointed out, I found very little literature on the subject and was obliged to resort to specifications that had been prepared in other cities for similar materials, all of which, as I recall, simply called for a certain kind of brick prescribing certain requirements in the physical test without mentioning the nature of the clay or shale from which it was to be made. After some deliberation it was decided that the proper requirements for the physical tests for repressed vitrified paving brick for this district should be as follows:

In the abrasion test the maximum loss shall not exceed 20 percent of the original dry weight. In the absorption test the absorption of water by any one brick shall not exceed three percent of its dry weight, and the average resistance to crushing shall be not less than 7500 lb. per sq. in.

Following the introduction of these specifications the next work that was advertised brought about a decided protest on the part of certain brick makers in this locality to the effect that the requirements were excessive and that clay which would produce brick to meet these requirements could not be obtained in this locality, which if true placed the city in an embarrassing position. Upon further investigation of the subject it was found that paving brick could be obtained which would comply with the requirements of these specifications and to-day we find that some of the makers who at that time said that the material could not be produced have furnished brick to meet the requirements. Just what changes were made in the process of manufacture I have not been able to learn.

Upon the completion of the experiments and tests which are now being conducted at the Pittsburgh Testing Station and which Mr. Bleininger has so ably described I feel certain that valuable data and information will be produced to enable engineers to have a better understanding of the quality of clay and shale necessary for the different products.

Mr. J. S. Unger: I was impressed during the reading of the paper by one thought. The manufacture of clay products dates back to very early times. I believe, if my early schooling is correct, that the first authentic biblical labor strike we have on record was caused by the laborers refusing to work without straw.

I was also impressed with another thought: the difficulty of finding anything written, or of securing literature on clay products. I had occasion about two years ago to investigate in a general way some clay products, and I thought of course I would be able to secure literature on the subject. After careful search I found I could secure some books de-

voted to the manufacture of porcelain, terra cotta, crockery, stone ware and material of that kind, but at that particular time I was looking for something relating to the manufacture of high grade refractories, such as high grade fire brick, and I was very much surprised to find that the only information I could secure was an occasional article, or a paper published by some of our technical journals, or read before some society.

Mr. H. H. Rankin: I would like to have an expression from the speaker as to the relative value of the so called paving blocks as compared with paving brick.

The Author: The paving blocks are replacing the bricks all over the country and it is now conceded that they are superior to the latter. The number of joints is of course decreased and the fact that the units are heavier seems to contribute towards greater stability of the pavement.

The growth in the demand for paving blocks is phenomenal and with the improved methods of laying as advocated by the National Paving Brick Manufacturers' Association this material is bound to become the most important pavement of our cities.

Mr. H. H. Rankin: The reason I asked is that I have had occasion to have both kinds tested and I never could see much difference in the wearing qualities of brick and paving blocks.

Mr. Edward Godfrey: I might suggest that the advantage of blocks in preference to bricks in pavement is that it gives a broader surface for each individual block in the foundation and distributes the load better, beside being fewer pieces to handle, making the paving cheaper in the laying.

Mr. J. O. Handy: The chemists who are here this evening are very much indebted to Mr. Bleininger for the many suggestions his paper contains. We are frequently confronted with the question as to what a clay or shale is suitable for, and almost as frequently are at a loss to give a definite statement on the point. Bleininger's method of classifying clays is certainly a very interesting one, and will be of a great deal of assistance.

We have had occasion to test some bricks recently for their acid resisting properties. Brick vary greatly in resistance to acids. These bricks were to be used in the chimney connected with the parting room of an assay office.

I want to express my personal thanks to Mr. Bleininger for his very interesting paper.

I would like to ask whether the discovery of Mr. E. G. Acheson that certain vegetable substances like tannin increase the plasticity of clays, has been of practical use in the clay industries.

The Author: Manufacturers of pottery are familiar with Mr. Acheson's discovery but practical tests have shown that, although the plasticity of clay is improved by the addition of tannin, certain defects in drying occur, such as warping which more than balances any gain in the working quality. The question has practically been dropped as far as the general manufacturers are concerned.

Mr. H. E. Ashley: While the tannin has not been adopted it is a fact that it has been the custom for many years to make additions to clay bodies, especially in pottery work, of other substances of colloidal nature, as tannin is, gelatine, glue, starch; stale urine, silicate of soda. They are all being added in special cases, generally to assist the cementing properties of a slip (such as the slip used in sticking handles on cups) or in some cases to diminish the amount of water required so as to decrease shrinkage (such as silicate of soda in the manufacture of sanitary ware by the casting process).

I have personally performed some tests on the addition of tannin to clays, and, except with fireclays containing soluble iron compounds, it has had very little special effect, much less than silicate of soda.

Silicate of soda seems simultaneously to decrease the amount of water required and to preserve the surface tension largely. Caustic soda and soda ash cut down both the water requirement and the viscosity.

Mr. L. P. Blum: I would like to ask whether there is any

simple test which could be recommended to determine whether an ordinary building brick will effloresce.

THE AUTHOR: I must say that there is no such simple test. The determination of the amount of soluble matter contained in clays is supposed to indicate whether or not the product will effloresce, but this does not necessarily follow. Besides, the determination as usually carried out is extremely inaccurate.

MR. R. H. YOUNGMAN: I am interested in this subject, particularly with respect to fire brick and other refractories. We have been familiar with clays not only in Pennsylvania and New Jersey, but in the west and in Alabama, and I think that all Mr. Bleininger has said which is applicable to our business agrees with our experience. The scope of his paper is very broad and his investigations will be of value to all clay workers.

There is one thing I might mention and that is the effect of alumina on clay. It is true that alumina is the only material you can add to a clay that will not decrease refractoriness, but alumina in almost any form has more shrinkage than other clays; you can burn it repeatedly and it keeps on shrinking. That is the principal objection to any brick containing a high percentage of alumina. It is very refractory and has a higher fusing point than clay and many other materials, and it will also better resist certain fluxes. It has not come into the same general use as the other materials, not only on account of the shrinkage, but also the high cost and irregularity of supply.

Bauxite is the purest form in which alumina is found naturally, and it must be calcined before it can be used for refractory purposes. The crude ore contains about 30 percent of water. It is mined extensively in France and in this country in Arkansas, Georgia and Alabama. The cost of transportation and calcining prohibits its extensive use as a refractory material.

A BITUMINOUS POWER GAS PRODUCER

By E. F. Bulmahn.*

Gas producers may broadly be divided into two classes, viz: pressure producers and suction producers. In a pressure producer, the air for combustion is introduced under pressure, usually by a fan or steam blower, the gas leaving under a slight pressure also, usually from one to three inches of water. A suction producer obtains its air for combustion by producing a suction at the outlet of the producer by means of an exhauster, or, as in the case of the smaller anthracite producers, by the engine itself. The question of the relative economy of these two classes of producers is more a matter of design than theory. However, considering the economy of the two as equal, the sanitary conditions attending the operation of the suction producer is enough argument in its favor. This will appeal particularly to those who have had some experience in obtaining labor to poke a pressure producer.

The two foregoing classes of producers are again divided into three distinct types, viz: Updraft, Downdraft and Double Zone producers.

The updraft producer is probably the simplest form of apparatus for the gasification of coals. Fuel is charged into the top of the producer and air for its combustion is introduced into the bottom, the gas being taken off at the top of the producer, above the fuel bed. The advantages of this type of producer are, that it makes a gas of high heat value and will completely consume the fixed carbon in the fuel. It has a decided disadvantage, however, in that a large percentage of the volatile matter in the fuel is carried off in the gas as tar. With fuels such as Pittsburgh coals, where the volatile matter represents from 35 to 40 per cent. of the heating value of the fuel, the thermal loss due to tar is well worth considering. The difficulties attending the complete removal of tar from gas and

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* Engineer with the Westinghouse Machine Company, Gas Producer Department.

its disposal are also a hindrance to the adoption of this type of producer.

In the downdraft producer the difficulty due to tar is overcome by introducing air on top of the fuel bed and taking the gas off at the bottom. By passing the volatile matter, given off during the coking of the coal, through incandescent car-

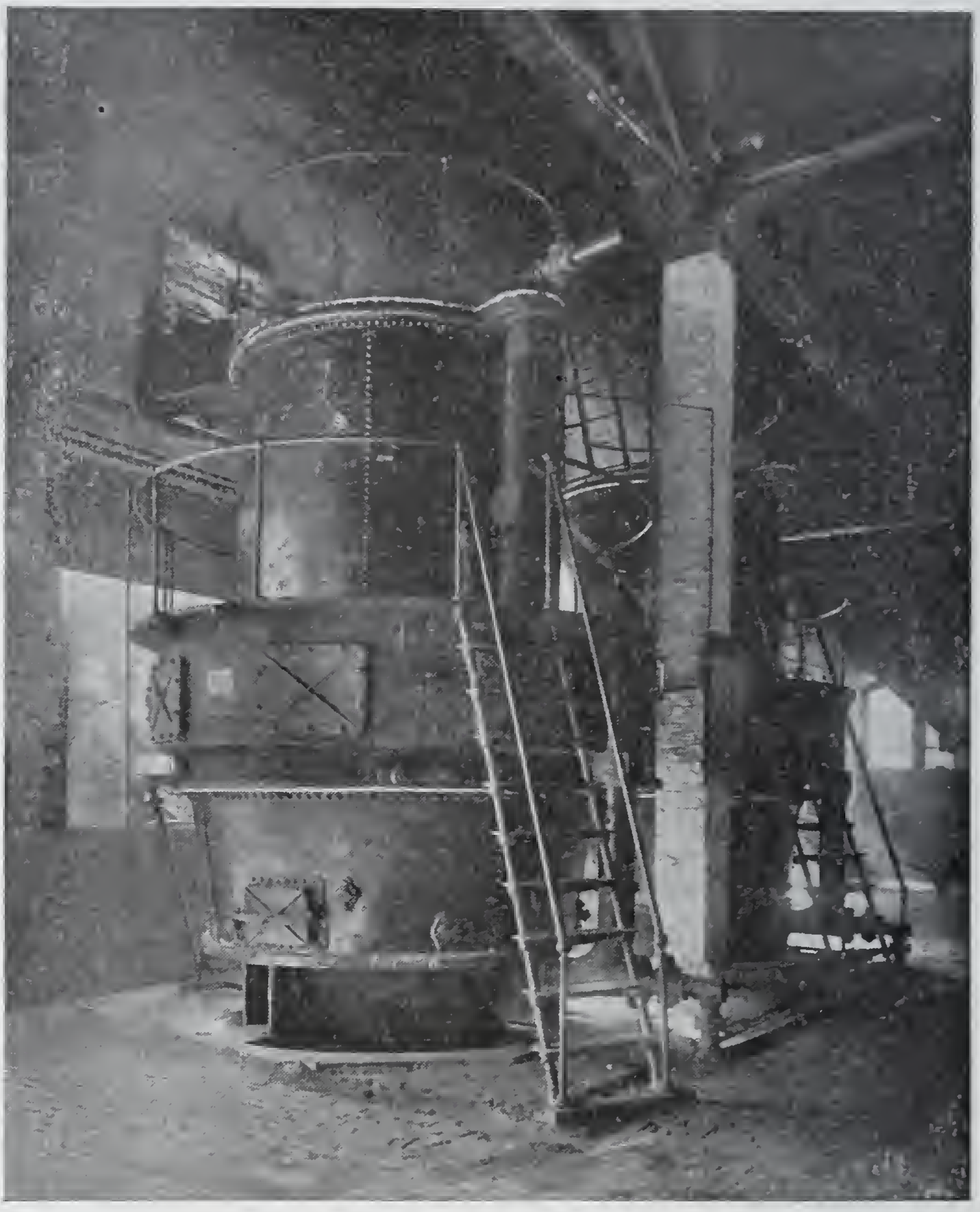

Fig. 1. Two 350 H. P. Units installed at Savannah, Ga.

bon, the tarry vapors are fixed into permanent gases, CH_4, H_2 and CO, producing a fixed gas free from tar. In this type of producer, however, it is impossible to completely consume the fixed carbon. The breaking up of the tarry vapors and the reduction of CO_2 to CO, requires from three to four feet of incandescent fuel. The oxygen introduced on top of the fuel

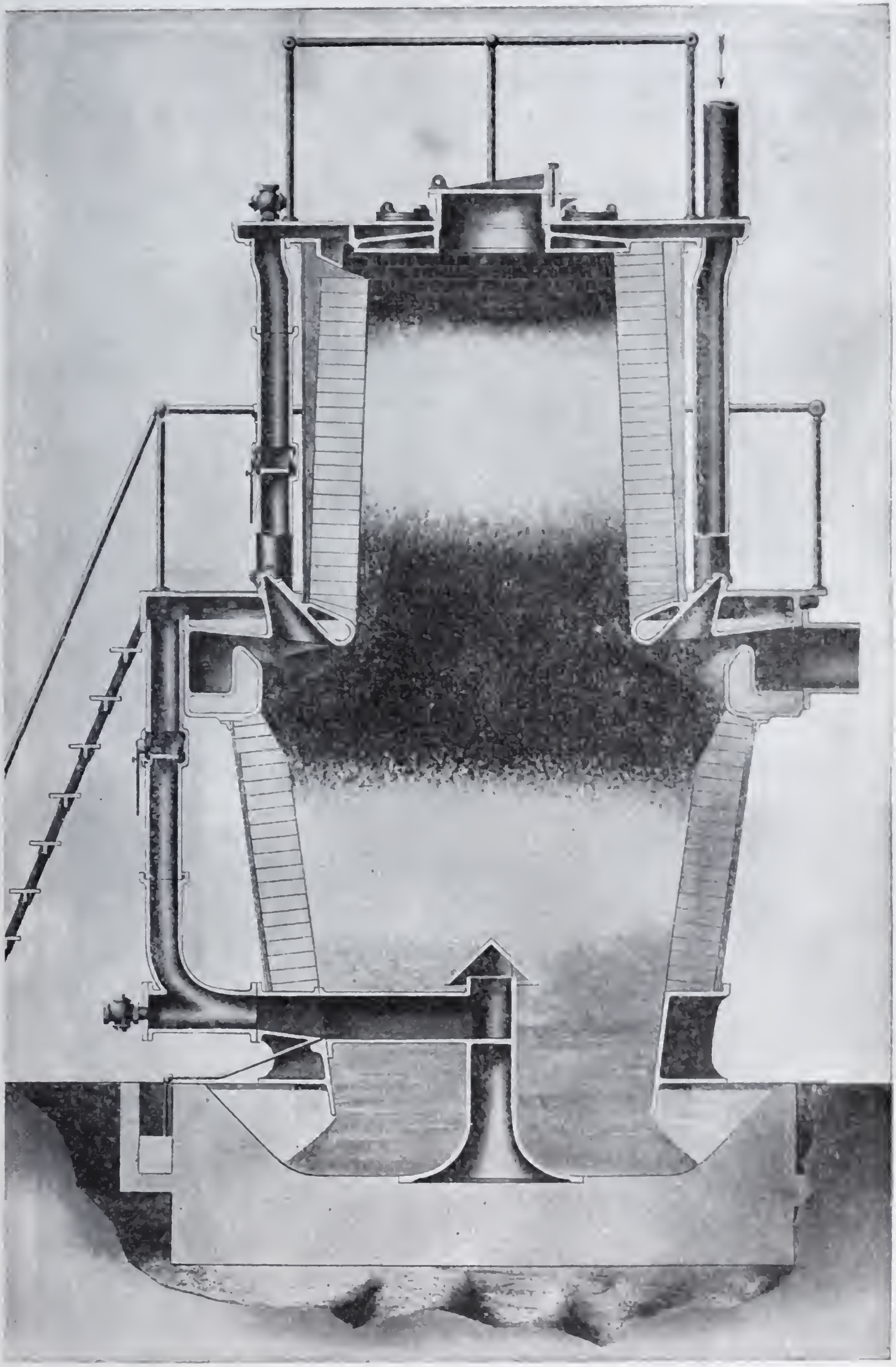

Fig. 2. Sectional view Westinghouse Double Zone Producer.

bed, after it has traveled about two feet below the top has combined with carbon to form CO_2 so that the only carbon recovered in the fixing zone is that taken up by the CO_2 gases in reducing to CO. This results in a high carbon loss in the ash.

The double zone producer, under discussion this evening, is designed to embody the good features of both the updraft and downdraft producers, overcoming the production of tar and completely consuming the fixed carbon. This is accomplished by having two distinct fuel beds, one operated as a downdraft producer, to break up the volatile matter, and the other operated as an updraft producer to consume to fixed carbon, the resultant gas from each zone being taken off at the center of the producer.

Fig. 2 illustrates a double zone producer, which consists of a top and bottom shell, interposed between which is a circular iron vaporizer, which furnishes steam for the producer and also serves to form the gas offtake. Air for combustion is drawn through the vaporizer, being saturated with water vapor, and is led through two pipes to the top and bottom fuel beds, the amount going to each one being regulated by two graduated cocks placed in the pipe line. The producer is of the water bottom design, permitting the removal of ash during continuous operation. The top of the producer is provided with a large coal charging door, which when opened allows the operator to examine the entire top of the fuel bed. Poking is provided for by a series of poke holes through the vaporizer to take care of the bottom fuel bed, the top being poked through holes located on top and through the charging hole.

In the operation of the producer, it is filled completely with incandescent carbon. Coal is charged on top of the fuel bed and air admitted for its partial combustion. The volatile matter given off passes downward through the incandescent carbon, where it is broken up into fixed gases. The coke formed passes down through the producer, being consumed in its travel through the bottom shell, until finally reduced to ash. The gas formed in the bottom fuel bed passes upward,

being taken off at the vaporizer with the gas from the top fuel bed.

From the producer, Fig. 3, the gas passes through a ver-

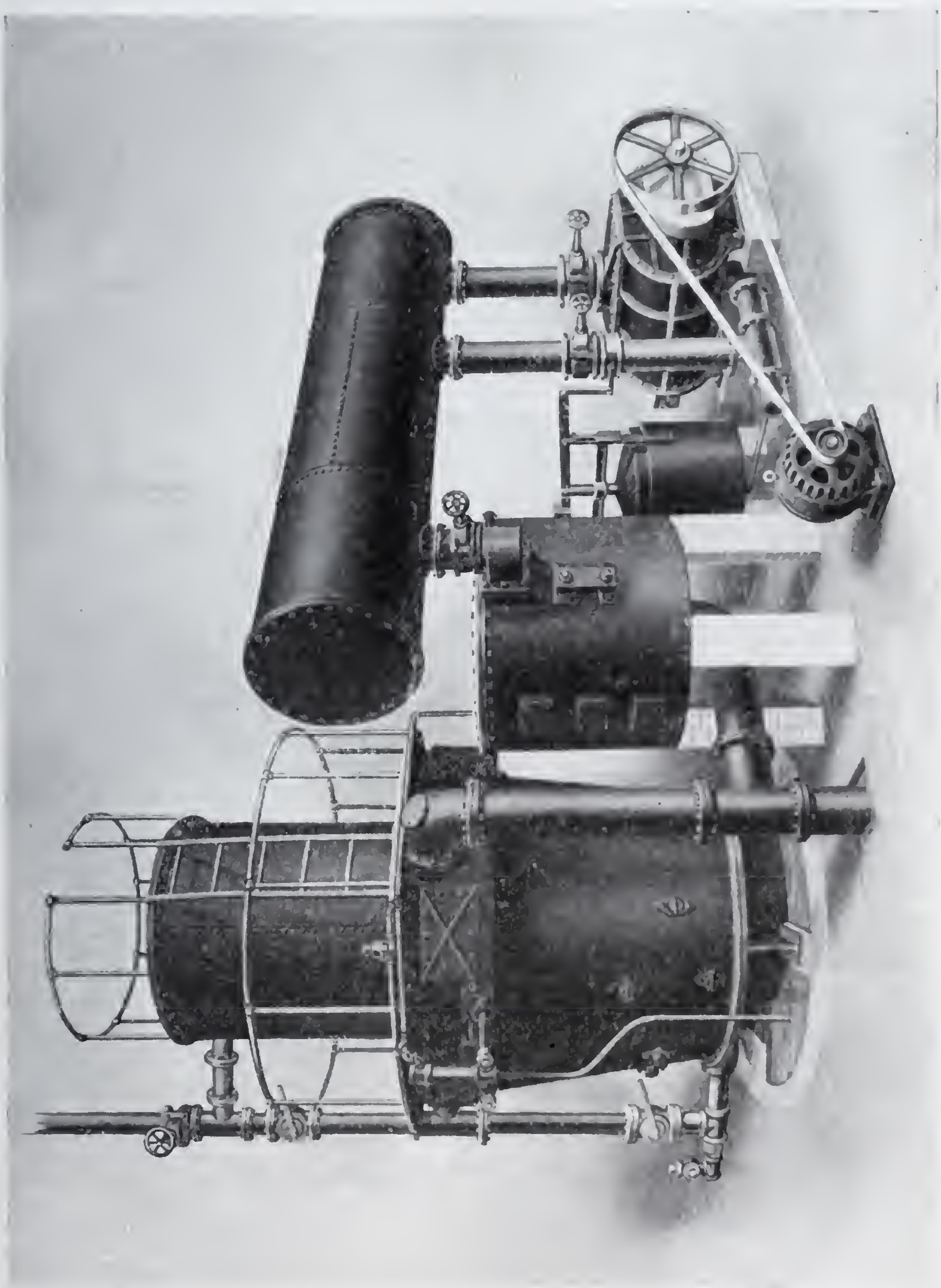

Fig. 3. Westinghouse Bituminous Gas Producer installation.

tical baffled pipe, provided with a water supply for the removal of heavy impurities, to the washer. The lower end of the pipe is dipped into a water seal and carries away the waste water.

The washer is a cast iron shell, containing a series of three perforated diaphrams, immersed in water. The gas passing through the small perforations deposits its solid impurities, consisting of light ash and lampblack, and is cooled by the incoming water supply. This type of gas washer and the absence of scrubbing material makes possible the continuous cleaning of the gas and displaces the mechanically driven high speed cleaning apparatus usually employed.

From the washer the gas passes into a cylindrical shell which is used as a mixing tank. The exhauster draws the gas from the mixing tank, maintaining a suction on the producer, and delivers the gas under pressure. When a fuel containing volatile matter is charged on an incandescent fuel bed, the gas given off during the first five minutes is highly enriched due to the hydrocarbons given off from the volatile matter. The usual method of overcoming this variation in the gas is to provide sufficient holder capacity to equalize the quality. In the producer under discussion, the exhauster delivers an excess quantity of gas, the excess passing into the mixing tank, where it is mixed with the lower heat value gas. The amount is controlled by a gasometer regulator and valve, which also serves to maintain a constant pressure in the gas outlet pipe. This gives a continuous circulation of gas through the mixer and insures an even quality of gas.

OPERATING RESULTS

At the experimental plant of the Westinghouse Machine Company a 51 weeks' continuous run was made on a 175 h. p. double zone producer and a 15 by 14, 3-cylinder gas engine. The plant was operated both 24 and 10 hours a day, the tests covering periods of from ten to thirty days. During this period the producers operated on South American lignite, Northern Colorado lignite, Pittsburgh Run of Mine coal, Pittsburgh Slack coal, New England peat, Texas Brown lignite and Pocahontas coal.

The relative composition of these different fuels is shown in table No. 1. Table No. 2 shows the economy of the producer and gas engine operating on the above fuels.

Test No.	KIND OF FUEL	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	BTU per lb. as fired
1	South American Lignite	20.32	34.44	30.58	14.66	1.05	8035
2	Northern Colorado Lignite	16.63	33.78	42.22	7.37		9589
3	Pittsburgh Run of Mine	2.03	34.98	56.22	6.77	1.29	13 305
4	Pittsburgh Slack	2.27	31.86	53.91	11.96	1.76	12 689
5	New England Raw Peat	38.10	40.54	17.86	3.50	0.19	6417
6	Texas Brown Lignite	23.83	38.32	29.22	8.63	0.57	8007
7	Pocahontas Run of Mine	1.39	16.01	74.28	8.32	0.69	13 983

TABLE No. 1

Test No.	Avg. Producer Efficiency.	Combined Producer & Engine Efficiency.	Pounds Coal. per B.H.P.Hr.
1	76.0%	Gas metered and purged out of stack.	
2	78.8	16.7%	1.59%
3	76.5	16.8	1.14
4	76.0*	14.5	1.37†
6	76.7	17.5	1.82
7	80.0	16.5	1.10

* Net efficiency.

† Producer operated 10 hours a day. Fuel consumption and combined efficiency includes stand-by coal 14 hours per day.

TABLE No. 2

The above tests demonstrate the adaptability of this type of producer to handle fuels, covering a wide range of heat values, and particularly the low grade fuels. The capacity of the producer was not materially affected by any of the different fuels, except peat, with which fuel the capacity was considerably reduced. The gas made from all the fuels was reasonably free from impurities, the solid matter averaging not more than .025 grains per cu, ft. of gas. As all the tests were made with the same engine, it afforded an excellent opportunity to note the effect of the gas on the engine. After a run of over

1000 hours, the inlet and mixing valves were removed from the engine for inspection. A slight coating of lampblack was found, but from all appearances it should have operated even a longer period without requiring cleaning.

The gas made on all the tests was of a good quality and reasonably constant in heat value. The average thermal value on bituminous coals was about 115 B. t. u., being a little higher on lignite gas. The heat value of this gas is rather low

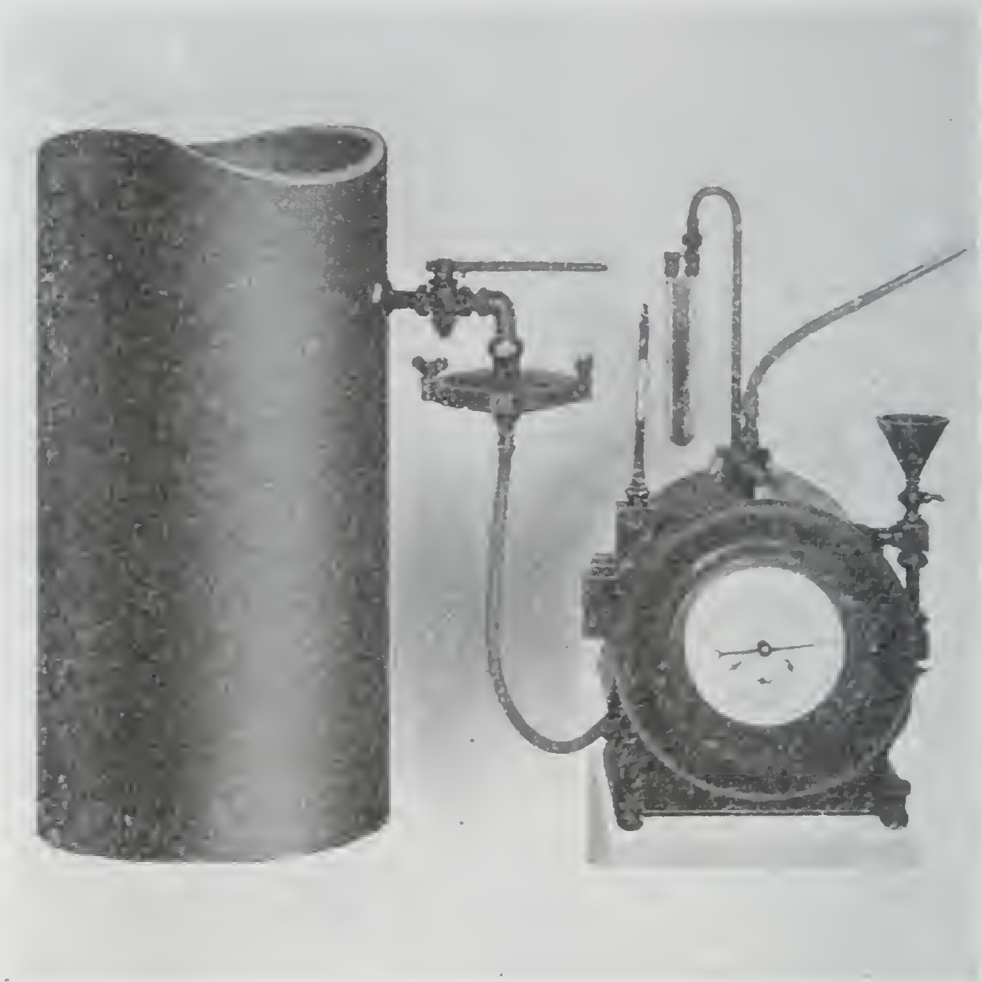

Fig. 4. Testing apparatus for determining solid impurities in gas.

compared with gas from an updraft producer. The reduction, however, is due to the lower H_2 and CH_4 content, a lower H_2 content being desirable for gas engine operation allowing higher compression and advanced ignition setting.

The labor required to operate the producer is comparatively small, it requiring about twenty minutes per hour of one man's time to perform all the labor on a 175 h. p. unit using a Pittsburgh coking coal.

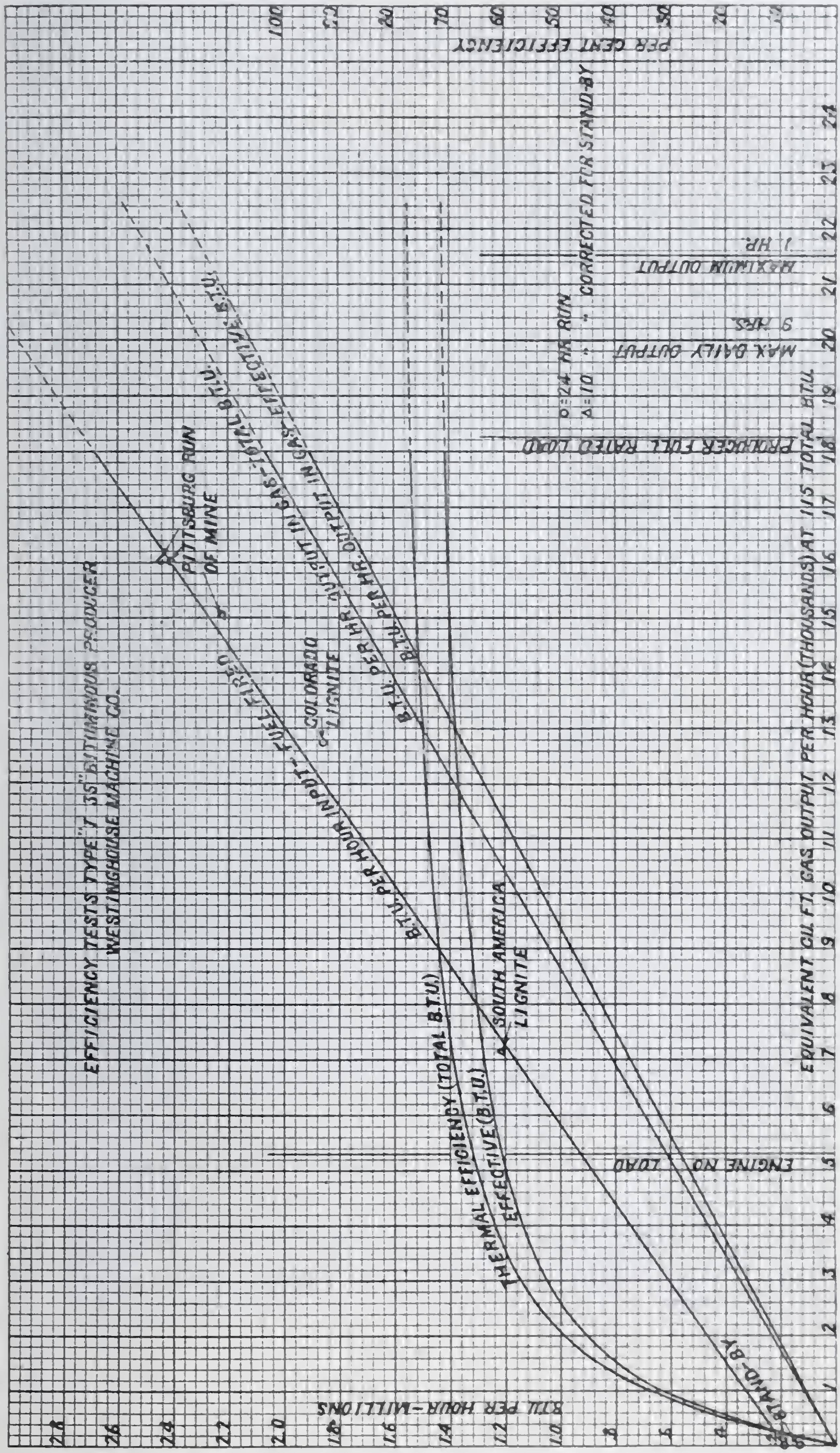

Fig. 5. Efficiency curve 175 H. P. Westinghouse Bituminous Gas Producer.

The standby loss of the producer when operating 55 hours per week represents about 0.9 per cent. of the fuel used when operating at full load.

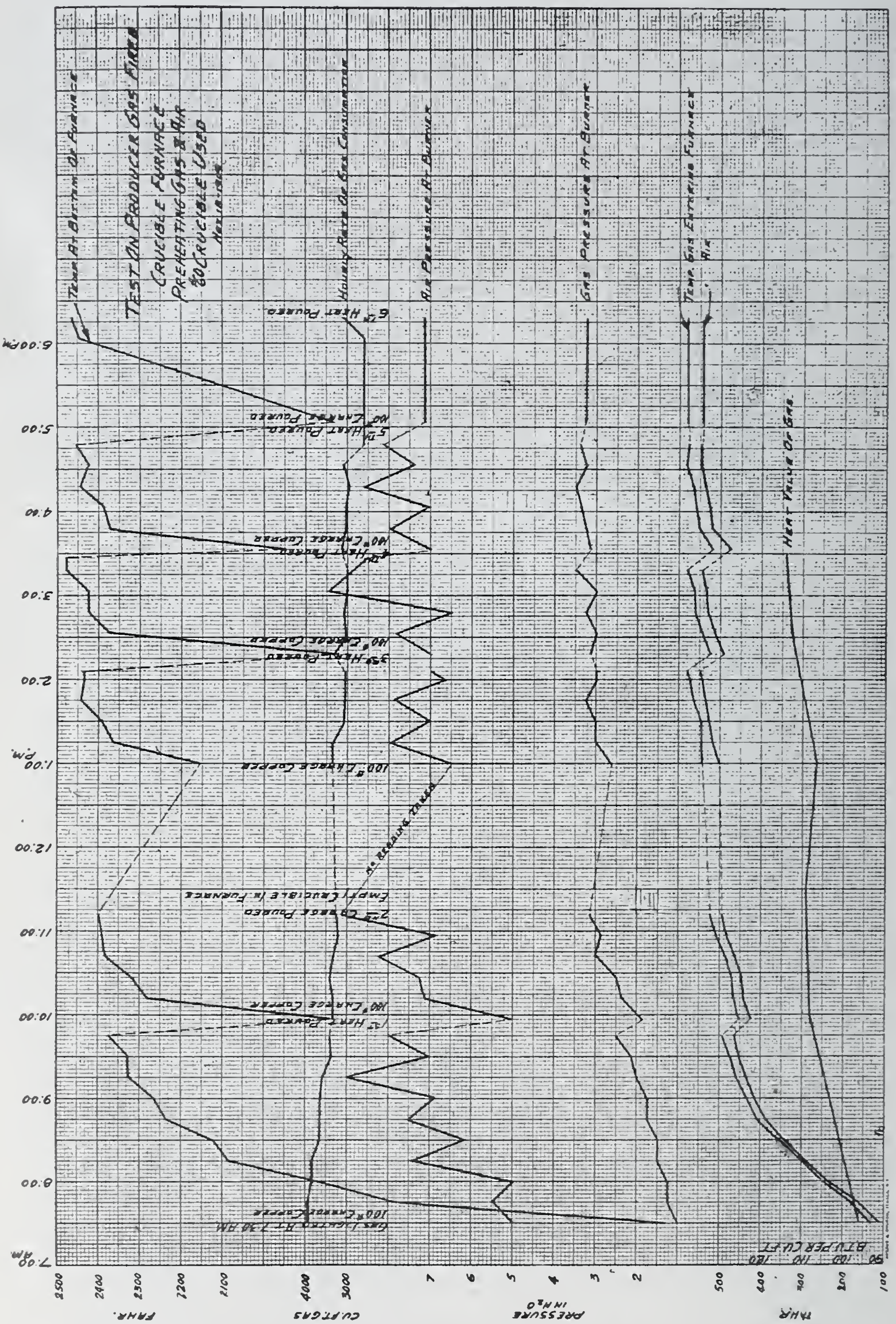

Fig. 6. Test on Producer gas fired melting furnace. Gas and air preheated.

Fig. 5 shows the producer efficiency curve, plotted from

the above mentioned tests. It is particularly interesting in that it conforms to so wide a range of fuels and the slight differences in the producer efficiency between one half and full load.

INDUSTRIAL APPLICATIONS OF PRODUCER GAS

The industrial application of producer gas offer a wide field for gas producers. They are now quite extensively used

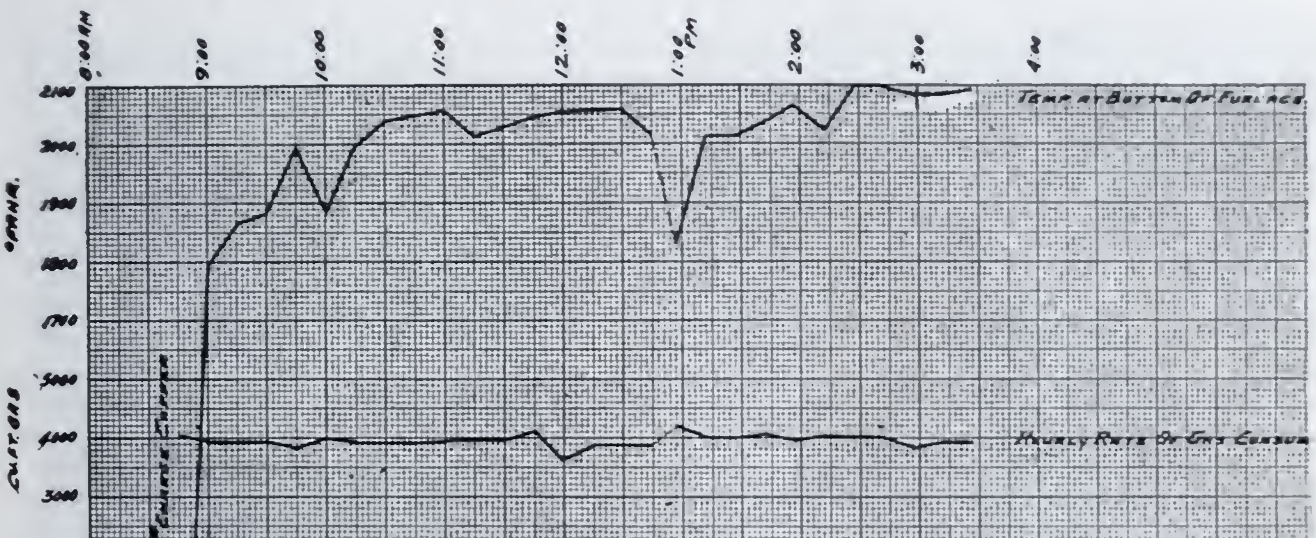

Fig. 7. Test on Producer gas fired melting furnace. Neither gas or air preheated.

in the manufacture of steel and glass, the producers being of the updraft type and the gas is used hot and uncleaned. There are a great many applications, however, where the gas must be distributed through small pipes, throughout a plant, and

consumed in small burners, and a cool, clean gas is required. This gas may be applied to small tempering furnaces, annealing ovens, enameling kilns, hardening, blueing and baking ovens, small melting furnaces, etc. It makes a particularly inviting proposition where power is required and a portion of the gas may be used as fuel, as the labor on the producer in most cases would be the same. Figs. 6 & 7 represent tests

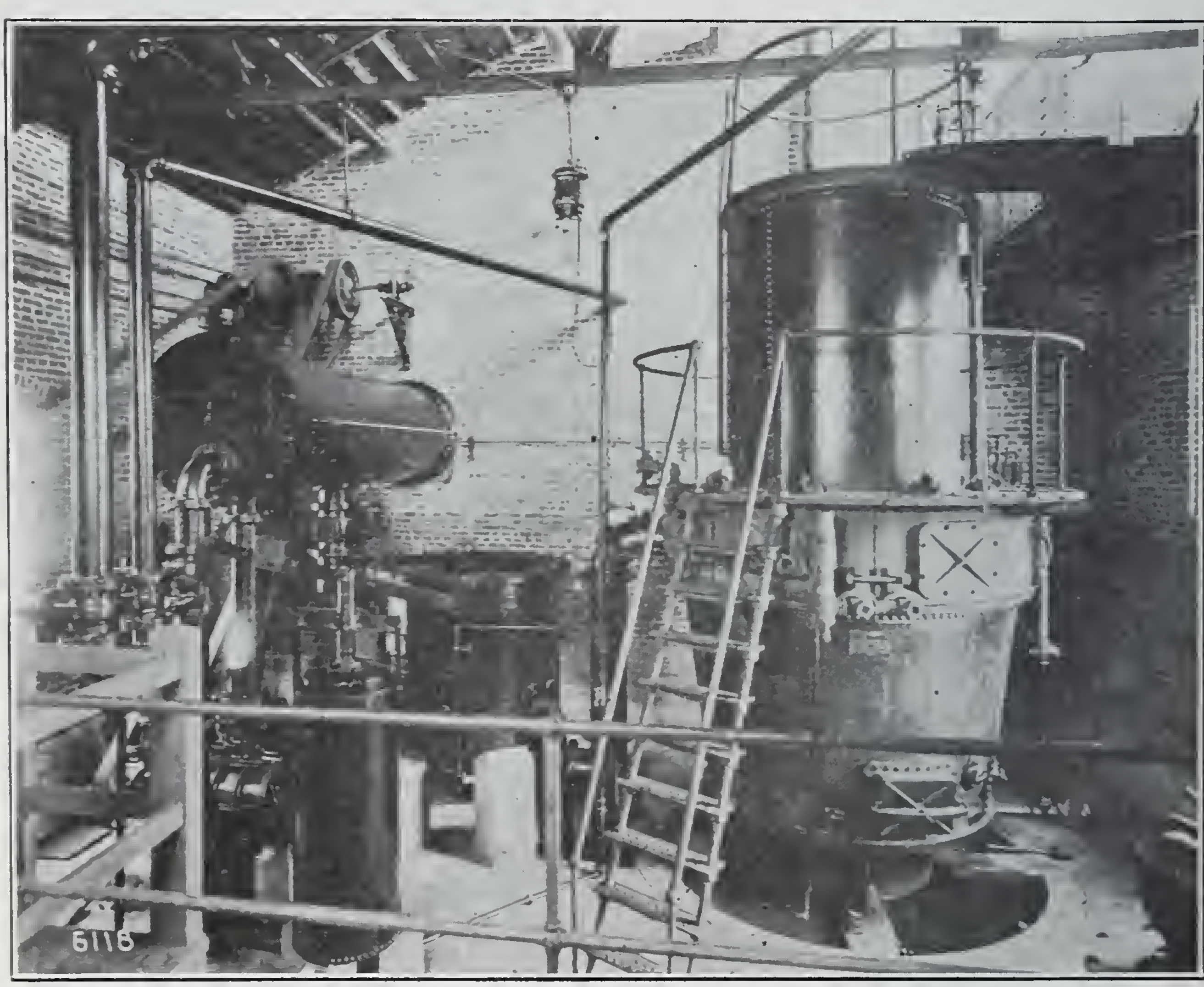

Fig. 8. 125 H. P. Producer installation.

on a No. 60 producer gas fired crucible furnace. Fig. 6 is a log of a day's test in which the gas and air were preheated, by utilizing the heat from the waste gases from the furnace; while in the test shown in Fig. 7 the gas and air were used at practically atmospheric temperatures. Particular attention is directed to the increased economy in the gas consumption with the preheat, the higher furnace temperatures attained and the

decreased amount of time required to take off a heat. In both of the tests 100 lb. charges of copper billets were melted down and poured.

Fig. 8 is a photograph of a 125 h. p. producer recently put into operation at the plant of the Alma Mfg. Company, Baltimore, Md., to replace illuminating gas formerly in use. The gas is used for japanning, tempering and blueing steel buttons and buckles. While no actual data is as yet available, the approximate saving in producer gas over illuminating gas including all fixed charges, will amount to about 40 per cent, or $140.00 per month, with illuminating gas selling at 80c per thousand cubic feet, and coal at $2.25 per ton.

DISCUSSION

Mr. J. K. Lyons: I would ask Mr. Buhlman to tell us what districts the Pittsburgh coals he tried out came from.

The Author: I can not say where the Pittsburgh coals we tried out came from, but the composition was about 35 per cent. volatile matter, 55 per cent. fixed carbon and the balance ash and moisture. Lignite is principally all volatile matter and moisture. In the Texas lignites the volatile matter runs about 40 per cent. and the moisture as high as 30 per cent. That would leave 30 to 35 per cent. fixed carbon and ash. In Pocohontas coal the volatile matter is as low as 17 per cent., the ash and moisture also being very low. This is the best coal we have tried out in the producer. Its heat value is about 14 000 B. t. u.

Mr. Richard Hirsch: I would like to ask whether the only fuel that gets to lower edge in the fire is that which has already been coked above?

The Author: In the operation of the producer, the idea is that in the top half of the producer all we expect to do is to coke the fuel and drive off the volatiles, the bottom working on carbon and ash only, so that the bottom fuel bed is operated as a simple updraft producer.

MR. J. K. CLEMENTS: What percentage of the total fixed carbon in the upper part of the producer gets down into the lower bed, and what percentage is broken up into CO? Do you have much trouble due to the formation of clinkers?

THE AUTHOR: After a year's run, which ended in April, we pulled the fire and took samples of the fuel from different parts of the producer. The coal was ordinary Pittsburgh Run of Mine and would run about 7 to 8 per cent. of ash. The fuel removed at the vaporizer analyzed about 15 or 16 per cent. of ash, so there is very little of the carbon consumed in the top fire, but just how much I do not know.

With a double zone producer there is less trouble from clinker than in a single flow producer, for the reason that having two combustion zones, with practically the same area, it gives a slower rate of combustion and a slower velocity through the fuel bed. This results in lower temperatures, preventing the formation of clinkers. Some clinkers are formed when starting the producer with a cold vaporizer. These usually form above the tuyere and are easily removed from the poke holes, of which there are about eight around the circumference of the vaporizer. On intermittant operation, it usually takes about 15 minutes after starting the producer before the average amount of steam is generated.

MR. J. P. LEASE: I would like to ask how this compares with the anthracite producer in economy and practicability.

THE AUTHOR: In this producer you have some impurities in the form of lampblack and probably a little higher carbon content in the ash than with an anthracite producer which causes a slight additional loss in the efficiency of the producer. The average efficiency of an anthracite suction producer I tested was about 80 per cent as against 77 per cent for the bituminous. As to the practicability of the two, while the bituminous producer requires a little more labor than the anthracite, I think it is today more reliable than the anthracite for this reason. With a fuel containing volatile matter and where you are not depending entirely on the work-

ing reaction, that is the combination of carbon and oxygen, a little irregularity in the fuel bed will not be felt as much in the bituminous as in the anthracite producer.

MR. O. L. GERWIG: Do you have to poke the fuel much at the top and how large units do you consider practicable?

THE AUTHOR: The fuel is charged in the top once an hour. Before another charge is put in the coke formed during the previous hour is broken up. That means about eight or ten minutes' work breaking up the top. Then we make a practice of going around the vaporizer casting about every 2½ hours and poking around the wall. That gives the fuel bed a better chance to settle where the ash is being formed. The average work on a producer amounts to probaly about 20 minutes in an hour on a 175 h. p. producer, excluding the wheeling in of the coal and the removing of the ash, which is usually done in the morning before starting up.

I believe it is practical up to 500 h. p., but how much above that will have to be determined in actual operation. A 350 h. p. producer is now in operation in Savannah, Ga., operating on Pocahontas coal.

A MEMBER: Does that compare favorably with gas in the Pittsburgh district at 12c per thousand? In the experimental work on these producers was any attention paid to the recovery of ammonia? With a low grade fuel like lignite or peat there is a possibility of much profit being obtained from the ammonia as a by-product. The Mond type of producer used in England, and in this country somewhat, reclaims ammonia to the extent of 60 lb. of the sulphate to the ton, which is almost enough to pay for the price of the coal. I should think with a producer of this kind it would be very easy to recover the ammonia if the volatile products are all drawn down through the fuel bed.

THE AUTHOR: Recently we made some comparisons between natural gas and producer gas. Figuring fuel, labor, interest and depreciation, natural gas would have to sell at

more than 20c per thousand cubic feet before producer gas could compete with it. These comparisons were made on Pittsburgh coals.

A Mond producer, as I understand it, is run chiefly as an apparatus for the production of ammonia, and the gas is more of a by-product. The ammonia is obtained by using a very much lower producer temperature than is used ordinarily. These lower temperatures necessarily produce considerably more hydrogen in the gas, which is very undesirable for power work. At these lower temperatures the ammonia comes off as NH_3, but at the higher temperatures the N_2 evidently combines differently. I have made some rough tests for ammonia but have only been able to find a trace at times. It is possible that if the waste water were used over and over again the liquor could be strengthened. Where the scrubbing water amounts to from 4 to 5 gal. per h. p. hour, I do not believe it would be commercially successful.

Mr. J. A. Smitmans: What economy did you obtain using peat as a fuel? In Fig. 2 what is indicated by the black band in the center of the producer?

The Author: With peat we found that the capacity of the producer was reduced about 40 per cent, while on Texas lignite, also a low heat value fuel, the capacity was not affected at all. The loss with the peat was probably due to excessive amount of moisture, (36 to 40 per cent), and to the peculiar characteristic of the fuel. No reliable data was obtained on the fuel economy.

The dark band referred to is to represent the fixing zone of the producer as being at a lower temperature than the combustion zones.

Mr. J. A. Smitmans: Does the combustion zone move down occasionally?

The Author: No, that is regulated in this way. In the operation of a double zone producer the success of the operation depends almost entirely on the regulation of the amount of air and steam taken into the top and bottom of the pro-

ducer. With a fuel containing a considerable amount of volatile matter, it requires more combustion on top to drive it off. If the rate of combustion is decreased the fuel bed will tend to lower itself. By increasing the amount of air to the top the temperatures are increased and the fuel bed may be built up. After the proportions of air and steam to the top and bottom fires have once been determined, they rarely have to be changed.

Mr. H. D. Fisher: What percentage of CO_2 do you get and what is the temperature of the gas leaving the producer? How does the capacity compare running with Pittsburgh slack and Pittsburgh run-of-mine?

The Author: The CO_2 runs from 7 to 9 per cent, the average being about 8 per cent. The temperature of the gas is very low, due to the waste heat being absorbed by the water in the vaporizer. On full load, it leaves the producer at about 500 deg. fahr.

The difference in capacity is not noticeable; from Texas lignite running 8,000 B. t. u. to Pocahontas coal, running 14 000 B. t. u. we did not notice any difference in the capacity of the producer. The low heat value of the lignite is due principally to the moisture. It seems that the moisture has not much effect on the capacity until it gets very high, as it is in peat when the capacity was reduced. I believe, however, that the characteristics of this fuel had considerable effect in reducing the capacity of the producer on this fuel.

Mr. J. O. Handy: What special kind of filter paper was used to determine the amount of dust or dirt in the gas?

The Author: A Baker & Adamson quality *B* paper was used. We have found that finer paper than this allows some of the impurities to pass through.

Mr. A. Stucki: Coming down to the question of direct heating for furnace work, I would like to ask as to the economy of producer gas in an updraft producer as compared with natural gas. Using Pittsburgh coal what do we really pay for producer gas in an up-draft producer? What is the rela-

tive size of an up-draft producer and the double zone producer? For the same amount of gas, how large is the producer in each case?

The Author: This type of producer is not adapted for furnace work. With an up-draft producer, using the hot gases in the furnace, the economy I think is about 90 per cent. Of course 90 per cent against 77 per cent would mean quite a reduction in the price of natural gas to compete with it. As to the comparative size of these two, taking combustion per square foot, I believe it is a trifle greater than a straight up-draft producer, that is because we have the two combustion zones.

Mr. A. Stucki: That would mean that natural gas would have to be sold somewhere around 15c?

The Author: I think a straight draft producer would compete with gas at 15c, using the hot gases.

Mr. J. K. Lyons: The following will afford a basis for comparing natural gas, fuel oil and fuel gas (producer) when applied to smelting or heating furnaces:

Calorific values are assumed as follows:

	British Thermal Units.
Natural Gas, per cu. ft.	1,000
Fuel Oil, per gallon	125,000
Fuel Gas, per cu. ft. (producer)	145

The following quantities are required for one million British Thermal Units:

Natural Gas	1,000 cu. ft.
Fuel Oil	8 gallons
Fuel Gas, (Producer)	6,900 cu. ft.

The following table gives the equivalent costs per thousand cubic feet for natural gas and per gallon for crude oil, when compared with producer gas generated from bituminous coal with recovery of Sulphate of Ammonia as a by-product.

It is assumed the plant will gasify not less than 48 tons of coal per 24 hrs.

Cost of Coal per Ton.	Equivalent price for natural gas per 1000 cu. ft.	Equivalent price for fuel oil per gallon.
$1.25	2.208 cts	0.276 cts
1.50	3.588 "	0.4485 "
2.00	6.348 "	0.7935 "
2.50	9.108 "	1.1385 "
3.00	11.868 "	1.4835 "

The above prices cover the cost of the coal and operating costs, but interest charges and depreciation and the auxiliaries are not included. If the fuel gas is used for operating internal combustion engines, the heat in the exhaust gases from the engines would be utilized in waste heat boilers, which would afford ample provision for all auxiliaries and without any addition to the operating costs.

Mr. H. C. Porter*: It might be of interest to state that at the Geological Survey fuel laboratories here there has been some study made of the character of the volatiles produced from different fuels and it was found that from the low grade fuels, for which this producer seems to be particularly well-adapted, a great amount of CO_2 is given off merely from the dry distillation of the coal. In the case of lignites and peats sometimes as much as 8 per cent of the fuel itself is found in the volatile matter as CO_2 without the use of any air at all, no CO_2 resulting from combustion. The first gases given off are sometimes as high as 50 or 60 per cent in volume of CO_2. It can readily be seen that in up-draft producers these volatile products would be drawn off and all that CO_2 lost, amounting to a large percentage of the fuel efficiency, while in this type of producer that CO_2 would be drawn down into the hot fuel and converted into CO, which is a big item in low grade fuel. Also the volatiles in low grade fuels are high in hydro-

* Chemist at the Pittsburgh Testing Station of the U. S. Geological Survey.

carbons heavier than methane which would partly be lost in the up-draft type. That may explain to some extent why this type of producer is of such great value for the low grade high volatile fuels.

THE AUTHOR: I might mention that when we were conducting the tests on Texas lignite we distilled off some of the volatiles in a retort and analyzed the gases and found that during the first period of the distillation of the CO_2 ran as high as 24 and 25 per cent and gradually reduced until the last portion of the gas given off was down to 2 or 3 per cent CO_2.

MR. H. C. PORTER: We found even higher than that, as high as 50 per cent in the first gas.

ABSTRACT OF MINUTES

FEBRUARY 1909 TO JANUARY 1910

ABSTRACT OF MINUTES

Engineers' Society of Western Pennsylvania

VOLUME 25

ANNUAL MEETING.

The Twenty-ninth Annual Meeting of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Fulton Building, Pittsburgh, January 19, 1909, at 8:30 P. M., President James K. Lyons presiding, 61 members and visitors being present.

The minutes of the last annual meeting were read and approved.

The annual report of the Board of Direction, including the reports of Standing Committees, Special Committees, Sections and the Treasurer, was read as follows:

REPORT OF THE BOARD OF DIRECTION.

The Board of Direction has held thirteen meetings during the year, at which the routine business of the Society was transacted, the monthly financial statements of the Secretary carefully inspected and reports from the various committees received from time to time.

At a special meeting of the Board, held April 17, 1908, resolutions were adopted expressing the deep interest of the Society in the matter of "Conservation of Our Natural Resources," which were forwarded to President Roosevelt, together with a letter noting the extensive list of papers presented at different times before the Society bearing on this subject. These resolutions and accompanying letters were presented to the Conference called by President Roosevelt for May 13, 14 and 15, 1908, to consider matters relative to the Conservation of the Natural Resources of the United States.

Copies were also forwarded to the Governor of Pennsylvania, our Senators and Representatives in Congress, to the Pittsburgh Chamber of Commerce and to the public press.

An amendment to Section 2, Article III, of the By-Laws,

was ordered published to the Society. The Society, by letter ballot, voted for the amendment as recommended by the Board.

At the meeting held November 7, 1908, Messrs. George T. Barnsley and E. K. Morse were appointed as delegates to represent the Society at the meeting of the American Mining Congress, held in Pittsburgh on December 2, 3, 4 and 5, 1908.

In the early fall Mr. Richard Hirsch resigned as Secretary of the Society. His resignation was accepted with regret, the Board expressing their appreciation of Mr. Hirsch's very efficient and loyal service to the Society. Mr. E. K. Hiles was elected Secretary, succeeding Mr. Hirsch.

There were held during the year nine regular, one special and the Annual Meeting, at which twelve papers were presented. The average attendance was 67, and the average number participating in discussion, nine. The maximum attendance was 93 and the minimum 47.

At the close of the year the membership of the society stood as follows:

Honorary members	7
Active members (three life)	809
Associate members	1
Jnior members	13
Total	830

During the year there were:

Resignations	45
Removals by death	3
Dropped from the rolls	38
Total	86

REPORT OF PUBLICATION COMMITTEE.

To the President and Board of Direction, Engineers' Society of Western Pennsylvania:

Gentlemen—We have made every effort during the past year to provide suitable entertainment for the members with the object in view of making them enjoyable from both a social and instructive standpoint.

Considerable difficulty has been encountered in trying to secure privileges to inspect plants which we considered would be of general interest. The main trouble seemed to be that on account of the hard times the various plants were not running full force and on this account they could not present as good an appearance as otherwise. During the year we provided one smoker and luncheon and seven inspection trips, as follows:

Inspection of the Seventh Avenue Telephone Exchange Plant of the Central District and Printing Telegraph Company, Pittsburgh, Pa., Saturday afternoon, April 18. Attendance, 125. The telephone company furnished guides, who explained in detail the operation of the various pieces of apparatus. In addition, printed pamphlets were distributed, which described the development and operation of the telephone system in Pittsburgh.

Open air luncheon and smoker, Hotel Lincoln Roof Garden, Saturday afternoon, June 13. Attendance, 98.

Inspection of the United States Sanitary Manufacturing Company's plant at Monaca, Pa., Tuesday afternoon, July 21. Attendance, 110.

Inspection of the new 20 000 H. P. mill engine at the works of Mackintosh-Hemphill & Co., Pittsburgh, Pa., Saturday afternoon, September 26. Attendance, 350.

Inspection of the Universal Portland Cement Company's plant at Universal, Pa., Saturday afternoon, October 31. Attendance, 436. This was our banner trip of the year. Free transportation in Pullman cars and luncheon on the train during the return trip were furnished.

Inspection of the City of Pittsburgh's newly completed Filtration Plant at Aspinwall, Saturday afternoon, November 21. Attendance, 250. Refreshments were served by the city; also pamphlets describing the Filtration Plant were distributed.

Inspection of the Civic Association's exhibit in the Art Galleries of the Carnegie Institute, Thursday evening, December 3. Attendance, 100.

Inspection of the Carnegie Steel Company's Duquesne Works, Friday evening, December 9. Attendance, 250. An

opportunity was afforded to see the 20 000 H. P. mill engine in operation.

It is gratifying to the Committee to see the great amount of interest displayed by the members in these trips. You will note there has been an average attendance of 215.

We are now making arrangements for the Annual Banquet, the details of which will be announced later.

In addition to the inspection trips and banquet we recommend that the Society give one or two receptions during the coming year in the way of dancing, euchre and luncheon. We believe that this social feature will tend to get the members better acquainted with each other and will be an acceptable variation from the other meetings of the year.

Yours respectfully,

S. P. GRACE,

Chairman of Entertainment Committee.

REPORT OF HOUSE COMMITTEE.

To the President and Board of Direction, Engineers' Society of Western Pennsylvania:

The Auditorium has been used 63 times during the year, 21 times for Society meetings, 42 times for other associations.

The Society rooms have been open every Saturday night until 10 P. M., with a total attendance of 104 during the year, an average attendance of 2.

The chess players are making a special effort to have a good attendance on the last Saturday night of each month, which has been set aside as chess night. It is believed that very pleasant informal social meetings are possible if members will make a point to come out on Saturday nights.

A very fine 30-in. globe on a 3-foot stand has been added to the furnishings of the Society rooms and placed in the club rooms.

For the convenience of members telephone service was installed in the Club room.

Respectfully submitted,

WALTHER RIDDLE, Chairman.

REPORT OF PUBLICATION COMMITTEE.

To the President and Board of Direction, Engineers' Society of Western Pennsylvania:

I have the honor to present the report of the Publication Committee for the year ending January 19, 1909.

During the year the Committee has furnished a program for each meeting of the Society and has directed the editing and publishing of the Proceedings. The latter is probably the only record needed of the Committee's activities. A number of minor changes have been made, with a view to the improvement of the periodical, and a cover of new design has been used, which the Committee believes to be more suited to a journal of this character. A successful effort has been made to decrease the cost of printing through increased care in preparing matter for the printer.

The chairman feels that this report will be incomplete unless some mention is made of the great help he has received from the members of the Committee and the Secretaries who have held office during the year. The results obtained have been due chiefly to their work and constant attendance at the necessary meetings.

Respectfully submitted, HARRISON W. CRAVER,
Chairman Publication Committee.

REPORT OF FINANCE COMMITTEE.

To the President and Board of Direction, Engineers' Society of Western Pennsylvania:

Gentlemen—Your Finance Committee would report that they have held monthly meetings during the past year, at which the financial statements of the Secretary have been audited and approved.

Yours very truly, F. Z. SCHELLENBERG, Chairman.

ANNUAL SESSION OF AMERICAN MINING CONGRESS.

To the President and Board of Direction, Engineers' Society of Western Pennsylvania:

Gentlemen—The Eleventh Annual Session of the American Mining Congress was held in Pittsburgh, December 2, 3, 4 and 5, 1908. Your delegates appointed to attend and meet

with this Congress take pleasure in stating that they gave due attention to the work and deliberations of the Congress. They also served on two of the local committees, namely, the Badge Committee and Reception and Entertainment Committee.

The meeting of this Congress was a very timely one with especial reference to the Pittsburgh district. Just at this time no more appropriate place could have been named for its deliberations. Originally the work of the Congress covered the mining interests, which embraced the more precious metals. The work now covers all the mining interests. The last meeting gave particular attention to the development in coal mining, with especial refernce to the modern means of prevention of accidents. It would seem that the December meeting was scheduled for the psychological moment, because the disaster to the Marianna mine quickened the thought of all men engaged in coal mining; and with the establishment of a Government Experimental Station in Pittsburgh, the greatest good will result from this meeting. The work of our Pittsburgh Experimental Station is going to bear a great amount of fruit for the safety of coal mining from this time on.

The deliberations of the Congress, although in the heart of our coal mining district, was wide and varied. Its reports will contain a large fund of useful knowledge and the getting together of the many interests will do much to bring about a greater uniformity in many of our States in the matter of coal mining, as well as to formulate better ideas for uniform national laws pertaining to mining interests.

It is a purpose of the Congress to have our general Government recognize the importance of the mining interests. This, to be followed by the establishment of a Mining Bureau in Washington. It is ultimately desired to have a special Mining Department at Washington with a cabinet officer at its head.

It is gratifying that the Engineers' Society should be called upon to appoint delegates to take part in such a Congress. A matter of this kind is properly one of the objects of this Society. Such an organization as this, which has within its membership, experts in many lines of development,should be called upon on all occasions of great public interest for advice

and help in matters wherein technical skill is desirable. We are expecting that a printed report of the deliberations of the Congress will be gotten out in due time, and shall hope that the library of the Engineers' Society will obtain a copy, so that all the members may have the advantage of the knowledge which is to be printed.

Respectfully submitted,

GEO. T. BARNSLEY,
E. K. MORSE,
Delegates.

REPORT OF STRUCTURAL SECTION.

To the President and Board of Direction, Engineers' Society of Western Pennsylvania:

During the year five meetings were held, four of which were devoted to the reading of regular papers and one to a topical discussion. The average attendance was 34, and the average number participating in discussions, 10. The maximum attendance was 50 at the meeting given over to a topical discussion, and the minimum attendance, 21.

At the Annual Meeting held Tuesday, January 5, 1909, the following officers were elected for the ensuing year:

Chairman, J. A. McEwen.
Vice Chairman, H. S. Prichard.
Directors, J. E. Banks, Paul S. Whitman and V. R. Covell.

It is suggested that an effort be made to obtain some continuity in subjects for papers and discussions. A difficulty presents itself, however, in case a single paper is to be made the feature of each meeting, because it is not always easy to obtain suitable papers, and the difficulty is enhanced if the Chairman or Executive Committee undertakes to assign the subject; in which case it is necessary to find some one qualified and willing to take the trouble to write an interesting monograph on that particular subject. This difficulty may be obviated to some extent, however, if a subject is designated as a topic for general discussion, and notices of the same sent out far enough in advance to admit of some special preparation

on the part of members intending to participate in the discussion. It might also be well for the Chairman to specially request several members, known to be familiar with the proposed subject, to come prepared to take leading parts in the discussion.

It is believed that this will awaken a wider interest in the meetings and redound to the benefit of a larger number of the membership. The chief benefit will accrue to those who, by study and research, prepare themselves to participate in the discussions, and the aim should be to make this number as large as possible.

Respectfully submitted.

E. W. PITTMAN, Chairman.

REPORT OF THE MECHANICAL SECTION.

To the President and Board of Direction, Engineers' Society of Western Pennsylvania:

During the year five meetings were held, at which six papers were presented. The average attendance was 36, and the average number participating in discussions, 12. The maximum attendance was 55, and minimum, 18.

The sections were formed with the object of extending the usefulness of the Society and to increase the interest of its members in the organization. That they have been conducive to this end stands without question, and a percentage of the recent additions to the Society's membership has been attracted by the influence of the sections, and comes as the result of the meetings they have held. Of first and vital importance is the securing of strong papers upon live and interesting topics, and scarcely less so is that a large attendance be assembled to listen to the readings, and that among those present there shall be a sufficient number who will do justice to the subject presented by a thorough and searching discussion in all its bearings. To this end it would be well if the authors could be induced to furnish the Secretary of the Society with a short synopsis of their papers two weeks or more in advance, for his use in connection with notices of meetings. With this indication of what is to be presented,

many may be induced to come prepared with valuable additions to the discussion, who might otherwise remain silent, or perhaps not even attend the meeting. Special efforts should be made to have the papers prepared as generally as possible by members of the Society,while still recognizing the value of all that has come from the outside in the past, and with the expectation of showing full appreciation of such contributions in the future.

Informal meetings might be aranged for to take place in the Society's club rooms, at which a general discussion would be had of topics of live interest, based, for instance, upon a reading of articles in the technical press.

The recent organization of a "Gas Power Section," by the American Society of Mechanical Engineers, indicates the conviction that certain benefits may be expected to accrue from concentrating attention upon a limited range of subjects, and that there are fields of usefulness to be occupied by the sections without in any way trenching upon the broader ground covered by the General Society.

Respectfully submitted,

GERALD E. FLANAGAN, Chairman.

REPORT OF TREASURER.

To the President and Board of Direction, Engineers' Society of Western Pennsylvania:

Receipts from all sources	$10,943.71
Disbursements	9,467.06
Excess of receipts	$1,476.65

INVESTMENTS.

Building Fund.

One, $1,000.00 Butler Water Company, 5 per cent. bond, No. 9, matures September 2, 1931	$1,025.00
Permanent Fund.	
Two, $1,000.00 Connellsville Water Company, 5 per cent. bonds, Nos. 317-318, mature October 1, 1939	2,020.00
Two, $1,000.00 Portsmouth, Berkeley & Suffolk Water Company, 5 per cent. bonds, Nos. 465-466, matures November 1, 1944	2,000.00
One, $1,000.00 Manufacturers Light & Heat, 6 per cent. bond, No. 4266, Series K, matures May 1, 1914	1,010.00
One, $1,000.00 Manufacturers Light & Heat, 6 per cent. bond, No. 1183, matures February 2, 1909	1,010.00
Total, seven bonds	$7,065.00

RECEIPTS.		EXPENDITURES.	
Dues, 1908	$6,027.01	Administration	$2,954.83
Dues, 1907	184.75	Entertainment	1,124.11
Dues, 1906	13.00	House	2,575.56
Entrance fees	265.00	Library	2.00
Rent	220.00	General Society	298.64
Sale of Proceedings	310.91	Mechanical Section	68.50
Society pins	14.50	Structural Section	89.35
Advertising	2,301.82	Proceedings	1,999.80
Interest	512.27	Advertising	80.20
Advance payment	240.00	Miscellaneous, including membership list, medals, etc.	274.07
Banquet	800.00		
Miscellaneous	54.45		
Total	$10,943.71	Total	$9,467.06

	1908.	1907.	Decrease.
Total receipts	$10,943.71	$11,219.13	$ 275.42
Total expenditures	9,467.06	11,359.35	1,892.29
Surplus	1,476.65	....	....
Deficit	....	140.22	....

ASSETS.

Bonds	$7,065.00
Permanent fund	1,532.17
Building fund	491.55
General fund	1,774.61
Petty cash	250.00
Total	$11.113.33

A. E. FROST,
Treasurer.

Mr. George H. Danforth made the following report for the tellers appointed to canvass the ballot:

Total number of ballots cast	226
Irregular ballots	8
Legal ballots	218

The following gentlemen were declared elected:

President, George T. Barnsley.
Vice President, Walther Riddle.
Treasurer, A. E. Frost.
Directors, J. N. Chester and S. A. Taylor.

The President appointed Messrs. Chester B. Albree and William A. Bole to escort to the rostrum, the President-elect, who was received with great enthusiasm and greeted the Society in the following address:

Gentlemen of the Society: You are very kind. I thoroughly appreciate the reception you are giving me. I am inclined to think, however, that like all men of the engineering profession, you are particularly large-hearted and full of good fellowship, and therefore feel that I have won the way to your hearts through those qualities of yours rather than through merit.

I appreciate the great honor you have conferred upon me. To be the President of an organization like this one, which has been developing for nearly 30 years, and one with a galaxy of men to watch over and guide its affairs, is of no small consequence. I feel rather serious regarding this position to which you have elected me, but, with your co-operation and your assistance, and with your kindly help, I am going to hope and trust that this year of 1909 will be full of good things, which will help develop the Society on the high plane on which it now stands.

There is a great deal to do. There is a great deal that can be done. I ask you to help in this development in every way you can. We have been running along successfully. We have gathered together much in the way of engineering development. We come here, of course, to exchange ideas on engineering matters; to present scientific subjects, with written papers on the best possible plane, and to develop good fellowship; which, of course, belongs especially to the men of the engineering profession.

I now ask you to take an interest in a wider field. In this field which I hope to see developed there are questions of great moment to the State and Nation. The Conservation of Natural Resources, River Development and such matters. Then there are questions of immediate need to this locality, such as rapid transit, sanitation and a new survey of the city. All of these are technical matters, to aid the highest development of civic affairs surrounding us. It is only proper that

we should take a broad interest in these questions and be a help to those who have the administration of them.

I do not mean to be radical. Do not for a moment think that. There is a proper way to influence these questions and there are no better men than those connected with this organization to bring it about. The men of this organization are the makers of Pittsburgh in their individual capacities. Collectively they should be the makers of broad public questions in the future, especially in all matters where technical knowledge, and skill, and advice are required.

I hope that during the year we can develop our social side; that we can get together more in a social way, where we can "eat, and drink, and talk, and think," as has been said by the very honorable Past President, the first President of this organization. He put it in those words, and I feel I can do nothing better than to repeat them and urge that we carry the thought along.

I thank you very much for your generosity, for your bigheartedness, and I hope to have your advice, your good fellowship and your association, on any questions that may come up for the benefit of this organization, which has more than a local meaning. Its membership reaches all sections of the world. It is one of the so-called local organizations which approaches nearer a national society than any other of which I have knowledge. I sincerely thank you.

Mr. James K. Lyons made an address as the retiring President, presenting the more important achievements of the past year in the engineering world.

The meeting adjourned at 9:55.

E. K. Hiles,
Secretary.

MEETING OF STRUCTURAL SECTION.

The Annual Meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held in the Society Rooms, Fulton Building, Tuesday, January 5, 1909, Chairman E. W. Pittman presiding. Forty-one members and visitors being present.

The minutes of the last Annual Meeting were read and approved.

The address of the retiring Chairman was postponed until after the business of the Annual Meeting.

The Nominating Committee presented their report as follows:

Chairman Structural Section, Engineers' Society of Western Pennsylvania:

We the undersigned Nominating Committee, beg to report the following officers for 1909:

For Chairman, J. A. McEwen.

For Vice Chairman, Henry S. Prichard.

For Directors, J. E. Banks, Paul S. Whitman and V. R. Covell.

Respectfully,

T. J. Wilkerson,
Willis Whited,
R. B. Woodworth.

On motion the Secretary was instructed to cast a unanimous vote for the above nominees.

The Annual Meeting adjourned at 8:35 P. M.

Immediately following the Annual Meeting, the regular Bi-Monthly Meeting was called to order by Chairman J. A. McEwen.

Minutes of the last regular meeting were read and approved.

There being no regular business coming before the meeting, the address of the retiring Chairman, Mr. E. W. Pittman, on "Secondary Stresses in Frame Structures," was made. The discussion following the presentation of the address was participated in by Messrs. Prichard, Danforth, Wilkins, Whited, Laub, Whitman, McEwen and Pittman.

The meeting adjourned at 10:35 P. M.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Fulton Building, Pittsburgh, Saturday, January 9, 1909, at 8:25 P. M., President James K. Lyons presiding; the following members being present:

Messrs. Barnsley, Grace, Handy, Kintner, Craver, Frost, Schellenberg and the Secretary.

The minutes of the last meeting were read and approved. The applications of the following gentlemen having been favorably passed upon by the Board, at the meeting of December 5, 1908, and regularly published to the Society, were duly elected to membership:

ACTIVE.

John T. Barr,
John A. Ferguson,
Axel H. Helander,
Samuel M. Kier,
E. J. K. Mason,
John M. Milliken,
Donald McNeil,
Percy M. Snoeberger,
Thomas W. Smith.

JUNIOR.

Homer N. Bliss.

The applications of the following gentlemen were favorably acted upon:

ACTIVE.

John Allison,
Charles Harold Day,
James H. Grose,
Henry M. Hallett,
Harry D. Hildebrand,
William R. Matthews.

JUNIOR.

George E. Herrmann.

ASSOCIATE.

John K. Hallock.

The Secretary reported the deaths of Henry Aiken, December 11, 1908, and Joshua Rhodes, January 5, 1909.

The Secretary's report was presented, showing the financial condition of the Society at the close of business, December 31, 1908, which had previously been approved by the Finance Committee. The Secretary's report was approved as presented.

E. K. Hiles, Secretary.

REGULAR MONTHLY MEETING

The 291st regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday, February 16, 1909, at 8:15 P. M., President Geo. T. Barnsley presiding, 56 members and visitors being present.

The minutes of the last regular meeting were read and approved.

The Board of Direction reported the election of six Active, one Associate and one Junior members at the meeting of February 6, 1909. Favorable action was also reported on four applications for Active, and one for Junior membership.

The death of Mr. A. K. Ashworth was announced.

Mr. E. K. Hiles was elected Secretary of the Society for the ensuing year.

No other business coming before the meeting the paper of the evening, "The Manufacture of Portland Cement," was read by W. M. Kinney. The author used about 50 lantern slides in illustrating his paper.

The discussion following the reading of the paper was participated in by Messrs. Lyons, Walker, Handy, Blum, Hiles, Ferguson, Feicht, Judd, Norton, Godfrey and Kinney.

The meeting adjourned at 10 P. M.

E. K. Hiles,
Secretary.

MECHANICAL SECTION

The Annual Meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday, February 2, 1909, at 8:15 P. M., Chairman G. E. Flanagan presiding, 61 members and visitors being present.

The minutes of the last Annual Meeting were read and approved.

The report of the Nominating Committee was read as follows:

Chairman, Richard Hirsch.
Vice Chairman, H. D. James.
Directors, Chester B. Albree, H. C. Cronemeyer and F. W. Winter.

On motion the Secretary was instructed to cast a unanimous ballot for the gentlemen nominated, which was accordingly done.

Chairman Flanagan appointed Messrs. L. C. Moore and E. V. Wurts a committee to escort the Chairman-elect, Richard Hirsch, to the platform, who responded with the following address:

Gentlemen: It certainly gives me very great pleasure to have been elected to the position of Chairman of the Mechanical Section of this Society, and I hope I shall be able to discharge the duties of the office as creditably as my predecessors have done.

If I were to make any remarks at this time, they would be along the lines followed by Mr. Geo. T. Barnsley two weeks ago, upon the occasion of his induction into office as President of the Society. I would dwell particularly upon those of his remarks wherein he spoke of the position which the Society should occupy in this community. Our members are known individually, by their works, throughout the civilized world. I do not think there is a country on the face of the earth to which the Pittsburgh engineer has not sent his work—from Finland and Japan, to South Africa and Australia—from Alaska to Argentina. If our members were to file past the globe in the other room and pin a minature American flag upon the localities where each has sent his work, the Stars and Stripes would float in the breeze in every land and clime.

An organization with such a membership ought to be a power in the community in which it lives. The events of the day show very conclusively that the time has come when, not only this Society, but every organization of a similar nature, should take an active interest in public affairs. We

are a technical body—not civic or political; but as the government of a great city like ours involves, to so great an extent, questions of a purely engineering nature, it is entirely within our province to take an active interest in civic matters. A number of years ago, upon the occasion of the head of one of the city departments advocating a certain public improvement, which, from an engineering point of view, was a most impracticable proposition, involving a great expenditure of money with but very questionable benefits, a resolution was presented to the Board of Direction, setting forth that this Society as a body did not approve of the undertaking. The resolution was laid on the table—the consideration of such questions being deemed an unwise procedure. We state in our Proceedings that the "Society does not hold itself responsible for the opinions of its members." The necessity for this is perfectly clear. A member might advance an opinion which the Society could not endorse; but there are many reasons why the Society as a body should advance an opinion, or advocate a principle. I would not advocate that we engage in politics in the common acceptance of the term, or assume an undignified position in dealing with public questions. The opinion of the Engineers' Society of Western Pennsylvania, upon public matters of an engineering nature, should have the weight of a report of an appointed commission. I believe the personnel of our members is of too high an order for this Society to lead merely a passive existence.

An address, "The Engineer, and the Engineers' Society," was then delivered by the retiring Chairman, G. E. Flanagan.

The Annual Meeting was then adjourned and the regular bi-monthly meeting called to order by Chairman Hirsch.

The minutes of the last regular meeting were read and approved.

The meeting was devoted to a discussion of the paper on "Electrically Operated Brakes for Industrial Purposes," by H. A. Steen, which was read at the regular meeting, October 20, 1908.

The discussion was participated in by Messrs. James,

Stevenson, Hiles, Flanagan, Klindworth, Wiley, Brosius, Moore and Steen.

The meeting adjourned at 10:10 P. M.

E. K. HILES, Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Fulton Building, Pittsburgh, Saturday, February 6, 1909, at 7:50 P. M. President Geo. T. Barnsley presiding, the following members being present:

Messrs. Morse, Riddle, Handy, Craver, Grace, Chester, Frost, Schellenberg and the Secretary.

The minutes of the last meeting were read and approved.

Mr. E. K. Hiles was elected Secretary of the Society for 1909.

The applications of the following gentlemen having been approved and regularly published to the Society, they were duly elected to membership:

ACTIVE

John Allison,	Henry M. Hallett,
Charles Harold Day,	Harry D. Hildebrand,
James H. Grose,	William R. Matthews.

ASSOCIATE

John K. Hallock.

JUNIOR

George E. Herrmann.

The applications of the following gentlemen were favorably acted upon:

ACTIVE

Charles E. Augustine.	Samuel Fray, Jr.,
Arthur E. Crockett,	Luther K. Yoder.

JUNIOR

Robert Whyte.

The report of the Secretary, showing the financial condition of the Society at the close of business, January 30, 1909, was approved, and bills ordered paid.

E. K. HILES, Secretary.

REGULAR MONTHLY MEETING

The 292nd regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday, March 16, 1909, at 8:20 P. M., President George T. Barnsley presiding, 81 members and visitors being present.

The minutes of the last regular meeting were read and approved.

The Board of Direction reported the election of four Active members and one Junior at the meeting held March 5, 1909. Also applications for membership were received and ordered published to the Society as follows: Three for Active membership, one Associate and two Junior.

No other business coming before the meeting the paper of the evening: "Forging Car Wheels and Conditions of Steel for High Service," was presented by Jas. H. Baker. The author used a number of charts in illustrating the paper.

The discussion following the reading of the paper was participated in by Messrs. Joseph Morgan, G. L. Norris, Julian Kennedy, Samuel Diescher, Arnold Stucki, H. H. Anderson, S. S. Wales, F. D. Ward, H. J. Lewis and Jas. H. Baker.

The meeting adjourned at 10:10 P. M.

E. K. Hiles,
Secretary.

STRUCTURAL SECTION

The regular bi-monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Tuesday, March 2, 1909, at 8:20 P. M., Chairman J. A. McEwen presiding, 81 members and visitors being present.

The minutes of meeting of January 5 were read and approved.

No further business coming before the meeting the address of the evening, "Some Observations on Structural Shop Management," was made by Samuel E. Duff.

The ensuing discussion was participated in by Messrs.

Gerber, Neeld, Albree, Lincoln, Kratzer, Hunter, Wilson, Lyons, Banks, Manning, Prichard, Godfrey and Duff.

The meeting adjourned at 10:05 P. M.

E. K. HILES, Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Friday, March 5, 1909, at 5:30 P. M., President George T. Barnsley presiding, and the following members present: Messrs. Riddle, Handy, Frost, Lyons, Taylor, Schellenberg, Kintner and the Secretary.

The minutes of the last meeting were read and approved.

The applications of the following gentlemen having been favorably passed upon by the Board, at the meeting of February 6, 1909, and regularly published to the Society, were duly elected to membership:

ACTIVE

Charles Edward Augustine, Samuel Fray, Jr.,
Arthur Ewen Crockett, Luther Keller Yoder.

JUNIOR

Robert Whyte.

The applications of the following gentlemen were received and their names ordered published to the Society:

ACTIVE

Thomas Franklin Maloy, Courtenay R. Rothwell,
J. Hewin Toupet.

ASSOCIATE

John D. Ackenheil.

JUNIOR

Gustave Eugene Grabert, Jr.,
John William Todd.

The report of the Secretary, showing the financial condition of the Society at the close of business February 27, 1909, having previously been audited by the Finance Committee, was approved and bills ordered paid.

E. K. HILES, Secretary.

REGULAR MONTHLY MEETING

The 293d regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society's rooms, Fulton Building, Pittsburgh, Tuesday, April 20, 1909, at 8:20 P. M., President Geo. T. Barnsley presiding, 75 members and visitors being present.

The minutes of the last regular meeting, held March 16, and of the special meeting, held April 12, were read and approved.

President Barnsley reported on behalf of the Committee appointed at the special meeting, that the objectionable bill relative to licensing Civil Engineers had been held up in the Committee of the State Legislature, and not reported.

The Board of Direction reported the election of 3 Active Members, 1 Associate, and 2 Juniors, at the meeting held April 9, 1909. Five applications for Active membership and 2 for Associate, were received and ordered published to the Society.

No further business coming before the meeting, the paper of the evening, "The Work of the Clay Products Section of the United States Geological Survey," was read by Mr. A. V. Bleininger, Ceramic Chemist of the Pittsburgh Testing Station, of the Geological Survey. The author used a number of slides in illustrating his paper.

The ensuing discussion was participated in by Messrs. Sprague, Unger, Ashley, Rankin, Godfrey, Blum and Bleininger.

The meeting adjourned at 10:05 P. M.

E. K. Hiles, Secretary.

SPECIAL MEETING

A special meeting of the Society was called for Friday evening, April 2, 1909, to consider a bill, No. 1190, before the House of Representatives at Harrisburg, to establish a civil engineering council and a state board of examiners.

The meeting was called to order at 8:20 by President Barnsley, 43 members being present.

The bill was discussed by Messrs. Davison, Wilkins, Hopkins, Johnson, Nelson, Duff, Whited, Sshluederberg, Harris, Wilson and Woodworth.

Mr. W. G. Wilkins offered the following resolution which was duly seconded and passed in sections as follows:

1° It is the sense of this Society that a bill regulating the practice of civil engineering and surveying in the State of Pennsylvania is necessary.

2° That a committee of five be sent to Harrisburg empowered to ask the Legislative committee not to report this bill favorably, and

3° To state to the committee that it is the sense of this Society that a proper bill should be enacted, and that the Engineers' Society of Western Pennsylvania will endeavor to have the Engineers' Club of Philadelphia and the Engineers' Society of Central Pennsylvania appoint a joint committee to draw a bill that will be acceptable to the civil engineers and surveyors of Pennsylvania for presentation at the next session of the Legislature.

The meeting adjourned at 9:15 P. M.

E. K. Hiles,
Secretary.

After the meeting President Barnsley appointed the following committee in accordance with the above action: Thos. H. Johnson, Chairman; J. Toner Barr, Emil Swensson, W. G. Wilkins, J. W. Arras.

MECHANICAL SECTION.

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday, April 6, 1909, at 8:20 P. M., Chairman Richard Hirsch presiding, 71 members and visitors being present.

The minutes of the regular meeting of February 2d were read and approved.

No further business coming before the meeting, the paper of the evening, "Arc Welding," was read by Mr. C. B. Auel.

The discussion following was participated in by Messrs. Fisher, Stevens, Steen, Pirtle, Tinker, Palmer, Hirsch, Stucki, Hiles, Cox and Auel.

The meeting adjourned at 10:15 P. M.

E. K. HILES,
Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Friday, April 9, 1909, at 5:00 P. M., Past President James K. Lyons presiding, and the following members being present: Messrs. Handy, Craver, Frost, Taylor, Schellenberg, Chester and the Secretary.

The minutes of the meeting of March 5, 1909, were read and approved.

The applications of the following gentlemen having been regularly published to the Society, pursuant to the action of the Board on March 5, were duly elected to membership:

ACTIVE

Thomas Franklin Maloy, Courtenay R. Rothwell,
J. Hewin Toupet.

ASSOCIATE

John D. Ackenheil.

JUNIOR

Gustave Eugene Grabert, Jr., John William Todd.

The applications of the following gentlemen were received and their names ordered published to the Society:

ACTIVE

Thomas Leonard Andrews, Clyde Blaine Asher,
Robert Wilson McCasland, Daniel M. McBride,
Halfdan Andreas Steen.

ASSOCIATE

Kirke Porter Lincoln, Frank Howard Bailie.

The request for restoration to membership of Luther L. Knox was favorably acted upon and his name ordered placed on the Society rolls.

The report of the Secretary showing the financial condition of the Society at the close of business March 31, 1909, was approved, having previously been audited by the Finance Committee, and bills ordered paid.

The Secretary read the following financial statement of the banquet, held February 20, 1909:

RECEIPTS

Received payment for 250 tickets		$875 00

EXPENDITURES

Committee Ribbons	$ 2 50	
Index Cards	75	
Printing Notices	4 20	
Printing Tickets	2 00	
Entertainment	48 00	
Miscellaneous Expenses	1 30	
Stenographer	10 00	
W. R. Kuhn & Co.	765 45	834 20
Balance		$ 40 80

E. K. Hiles,
Secretary.

REGULAR MONTHLY MEETING

The 294th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday, May 18, 1909, at 8:20 P. M.; President Geo. T. Barnsley presiding, 121 members and visitors being present.

The minutes of the last regular meeting of April 20 were read and approved.

The Board of Direction reported the election of 5 Active members and 2 Associates at the meeting held May 7, 1909. Three applications for Active membership were received and ordered published to the Society. At a special meeting held May 18, 1909, to consider correspondence received from the Engineers' Society of Pennsylvania, inviting the Engineers' Society of Western Pennsylvania to send delegates to a convention to be held in Harrisburg on June 9, 10 and 11, the Secretary was directed to acknowledge letters received from the Engineers' Society of Pennsylvania, advising that, with the information now at hand the Board of Direction of the Engineers' Society of Western Pennsylyvania, do not authorize the appointing of delegates to take official part in the convention this year, but will, however, call the attention of our members to the coming convention.

No further business coming before the meeting the paper of the evening on "The Steel Beam" was read by R. B. Woodworth. The ensuing discussion was participated in by Messrs. Pritchard, Stucki, McEwen and Woodworth.

The meeting adjourned at 10:25 P. M.

ELMER K. HILES,
Secretary.

STRUCTURAL SECTION

The regular bi-monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Tuesday, May 4, 1909, at 8:20 P. M., Chairman J. A. McEwen presiding, 59 members

and visitors being present.

The minutes of the meeting of March 2 were read and approved.

No further business coming before the meeting, the paper of the evening was read by R. B. Woodworth on "The Steel Oil Derrick," and illustrated with lantern slides.

The ensuing discussion was participated in by Messrs. Moore, Yorke, Anderson, Stucki, McEwen, Albree and Woodworth.

The meeting adjourned at 10:30 P. M.

Elmer K. Hiles,
Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Friday, May 7, 1909, at 5:13 P. M., President Geo. T. Barnsley presiding, the following members being present: Messrs. Riddle, Handy, Graver, Grace, Lyons, Taylor, Schellenberg and the Secretary.

The minutes of the meeting of March 6, 1909, were read and approved.

The applications of the following gentlemen having been regularly published to the Society pursuant to the action of the Board on April 9, were duly elected to membership:

Active,

Thomas Leonard Andrews, Clyde Blaine Asher.
Daniel M. McBride, Robert Wilson McCasland,
Halfdan Andreas Steen.

Associate,

Kirke Porter Lincoln, Frank Howard Bailie.

The applications of the following gentlemen were received and their names ordered published to the Society:

Active,

Samuel E. Clarkson, Martin W. Hall,
Frank Milton Masters.

The report of the Secretary, showing the financial condition of the Society at the close of business April 30, 1909, was approved, having previously been audited by the Finance Committee, and bills ordered paid.

The Publication Committee presented the following recommendation:

"We recommend to the Board of Direction that the programs for the Sections of this Society be limited to Topical Discussions, consisting of oral or written presentation of the subject, the time for each participant to be from ten to fifteen minutes."

This recommendation was adopted, to become effective in September, 1909, without affecting programs already arranged in the Sections.

The meeting adjourned at 6:15 P. M.

A special meeting of the Board of Direction was held in the Society rooms, Tuesday, May 18, 1909, at 7:40 P. M., to consider letters received from the Engineers' Society of Pennsylvania under dates of May 10 and 17, inviting the Engineers' Society of Western Pennsylvania to send delegates to a convention of that Society to be held in Harrisburg on June 9, 10 and 11.

After discussion the Secretary was directed to acknowledge the letters received from the Engineers' Society of Pennsylvania, advising that, with the information now at hand the Board of Direction of the Engineers' Society of Western Pennsylvania do not authorize the appointing of delegates to take official part in the convention this year, but will, however, call the attention of our members to the coming convention.

Meeting adjourned at 8:09 P. M.

Elmer K. Hiles,
Secretary.

EMPLOYMENT BULLETIN.

The Society has found it can do an important work as the medium for securing better positions for its members who desire them. The Secretary gives this his personal attention, and is desirous of receiving prompt notification both of positions open and of men available. Notices are not repeated except upon special request. The list of men available is made up of members of the Society, and these are on file, together with names of men not members of the Society, who are capable of filling responsible positions. Information will be sent on application.

POSITIONS OPEN.

Engineers and draftsmen desiring positions are requested to register with the Secretary of the Society. We have recently had more calls for men than we could supply.

012 Wanted: Civil Engineer. A member of the Society leaving a good surveying practice within 75 miles of Pittsburgh, desires to dispose of instruments at low figure to engineer who will locate and take up the work.

013 Wanted: Sales representative by company manufacturing an up to date line of steam and gas engines.

015 Wanted: Capable man to take charge of drawing room; experienced in structural concrete design. Correspondence solicited from high grade men only.

016 Wanted: First class draftsman on mechanical work. No detailers.

MEN AVAILABLE.

14 Engineer with several years' experience as Master Mechanic for mining companies desires change. Experienced in installation work and operation. Technical education.

21 Position wanted by engineer and draftsman. Specialty, coal and coke plants. Broad experience, best references. Desires position as designer or chief draftsman.

22 Chemical engineer, technical education. Eight years experience. Three years with a steel company as analyst in ores, coal, coke, etc. Five years with one of the largest gas companies in the country as chemist and engineer in charge of by-product coke plant.

23 Position wanted by civil engineer in general engineering work. Technical education as civil and architectural engineer. Practical experience and exceptionally well fitted for analysis of complicated problems in hydraulics,structural and reinforced concrete work. Would form partnership if conditions were favorable.

REGULAR MONTHLY MEETING

The 295th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday, June 15, 1909, at 8:20 P. M.; President Geo. T. Barnsley presiding, 40 members and visitors being present.

The minutes of the last regular meeting of May 18 were read and approved.

The Board of Direction reported the election of three Active members at the meeting held June 4, 1909, and also the death of Charles Seymour Parsons.

Announcement of the following letter to the Aero Club of America was made:

June 7, 1909.

Aero Club of America,
Mr. De Witt C. Morrell,
Chairman Committee on Medals,
New York City, N. Y.

We take pleasure in adding our felicitations to your Club on the occasion of your presentation of the gold medals to the Wright Brothers through the President of the United States, in the White House, on June 10th, 1909, in commemoration of their achievement in the art of flying.

These felicitations upon our part are all the more enhanced by the fact that one of the members of our Society, Past President John A. Brashear, was closely associated in the past with Samuel Pierpont Langley, in his determinations of the laws governing flight by long and patient research, and we are cognizant of the fact that the Wright Brothers, to whom you will award the medals, have not only made themselves conversant with Professor Langley's epoch making studies, but have generously given their unqualified recognition of his investigations, from a scientific standpoint; and we have every reason to believe that if Professor Langley were with us today he would be one of the first to do honor to these men for their experiments and masterly achievement in heavier than air flying machines. It is also our pleasure to record the fact that Professor Langley was enabled to carry on his investigations and experiments above referred to by the generous gifts of money from one of our leading Pittsburgh citizens, the late William Thaw.

The Engineers' Society of Western Pennsylvania is in hearty sympathy with the Aero Club of America in doing honor to Wilbur and Orville Wright. While congratulating you for the encouragement and help you have given to investigators and inventors in the domain of experimental aeromatics and aviation, we also desire to express the wish that this comparatively new field of Engineering may receive a greater impetus by the splendid success attained by Wilbur and Orville Wright, and that the final outcome may be for the good of all nations, even to the hastening of the time when "they shall learn war no longer, and we shall see eternal peace spread her beneficent wings over the whole earth."

Respectfully submitted,
By order of the Board of Direction,
GEO. T. BARNSLEY,
President.

Attest:
ELMER K. HILES,
Secretary.

President Barnsley announced the receipt of letters from the Pittsburgh Alumni Association of Columbia University, inviting the Engineers' Society of Western Pennsylvania to select two young men as candidates, one of whom is to receive a free scholarship in Columbia University which carries a monetary value of $1000.00.

No further business coming before the meeting the paper of the evening, "Economy in Cupola Melting," was read by J. W. Henderson. The ensuing discussion was participated in by Messrs. Bole, Koch, Albree and Henderson.

The meeting adjourned at 10:05 P. M.

ELMER K. HILES,
Secretary.

MECHANICAL SECTION

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday, June 1, at 8:25 P. M., Chairman Richard Hirsch presiding, 70 members and visitors being present.

The minutes of the meeting of April 6 were read and approved.

The Secretary announced the proposed convention of the

Engineers' Society of Pennsylvania on June 9, 10 and 11 at Harrisburg.

No further business coming before the Section, the discussion of the evening on "Steel Castings" was opened by Mr. A. Stucki with a short paper on "Some of the Troublesome Features." Mr. John Allison presented a short paper on "Points to be Observed in Design." "Notes on Foundry Methods," by Mr. G. W. Smith, were read by the Secretary. Mr. J. S. Unger discussed the subject of "Heat Treatment." Mr. T. D. Lynch and Mr. C. B. Albree discussed the subject from the consumers' standpoint. After further general discussion the meeting adjourned at 10:20 P. M.

Elmer K. Hiles,
Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Friday, June 4, 1909, at 5:10 P. M., President Barnsley presiding, the following members being present: Messrs. Lyons, Morse, Riddle, Kintner, Craver, Grace, Schellenberg and the Secretary. Past Presidents Metcalf, Swensson and Diescher were also present.

The minutes of the meeting of May 7, 1909, were read and approved.

The applications of the following gentlemen having been regularly published to the Society pursuant to the action of the Board on May 7, were duly elected to membership:

Active

Samuel E. Clarkson, Martin W. Hall,
Frank Milton Masters.

The death of Charles S. Parsons was reported by the Secretary.

The report of the Secretary showing the financial condition of the Society at the close of business May 31, 1909,

was approved, having previously been audited by the Finance Committee, and bills ordered paid.

A letter was read from the Aero Club of America re memorial letter for the Wright Brothers, and President Barnsley and the Secretary were requested to draw up a suitable acknowledgment, making suitable mention of Prof. Langley's work in aeronautics.

President Barnsley read letters from the President of the Pittsburgh Alumni Association of Columbia University inviting the Society to select two young men as candidates, one of whom is to receive a free scholarship in the University.

It was moved and carried that President Barnsley appoint a committee, of which he shall be Chairman, with full power to act in the selection of the two candidates after giving the matter due publicity in the printed announcement to the Society.

The meeting adjourned at 6:15 P. M.

ELMER K. HILES,
Secretary.

As this issue of the Proceedings goes to press the Society is mourning the sudden death, on October 23d, of President GEORGE T. BARNSLEY, who was probably the most active member the Society has had in recent years.

Suitable resolutions and announcements will appear in the next issue.

REGULAR MONTHLY MEETING

The 296th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday, 21st September, 1909, at 8:25 P. M.; Vice President E. K. Morse presiding, 50 members and visitors being present.

The minutes of the last regular meeting, June 15, were read and approved.

The Board of Direction reported the receipt of a letter from F. H. Snow, President of the Engineers' Society of Pennsylvania, inviting the Engineers' Society of Western Pennsylvania to appoint a committee of three to co-operate with similar committees from the various engineering societies in the State, to formulate a code for engineers to be presented to the State legislature. At a special meeting held August 3, President Barnsley was requested to appoint such committee. At the regular monthly meeting of the Board of Direction, held September 14, 1909, President Barnsley announced the committee authorized by the Board at its last meeting, consisting of himself as Chairman; Thos. H. Johnson and W. G. Wilkins; and the following as alternate and consulting members of the committee: Charles F. Scott and James K. Lyons.

Six applications were received for active membership, one for Junior and two applications for restoration to membership.

The deaths of the following members of the Society were announced:

Thos. Bakewell, July 7, 1909, who joined Society May, 1884;

Thos. Carlin, June 23, 1909, who joined Society May, 1885;

W. H. Singer, September 4, 1909, who joined Society September, 1880.

The Secretary having investigated the matter of the purchase of a reflecting lantern, was authorized to purchase same for use in the auditorium.

Announcement was made of the receipt of a communication from the Chairmen of the Section re limitations of

programs in the Sections. In view of the fact that the Publication Committee in recommending such limitations to the Board, and the Board of Direction in approving same, were unaware that the By-Laws do not place the programs of the Sections in charge of the Publication Committee. The Board withdrew their approval of the recommendation made by the Publication Committee.

The Nominating Committee for 1909 was announced as follows:

E. B. Taylor, Chairman,	G. H. Barbour,
Walther Riddle,	H. H. McClintic,

D. M. Howe.

A telegram was read from President Barnsley who, was unable to be present at the meeting.

The following resolution was presented by Chester B. Albree: "Whereas, as a result of a serious and careful study of the questions of the government and conduct of the Sections of the Engineers' Society of Western Pennsylvania, by a number of members who have had the welfare of the Society at heart, it seems desirable to have the present rules and By-Laws rectified so that the Sections and the General Society should be united under one general management, having control of all doings and proceedings, instead of control by separate boards as at present, and furthermore as the means and methods of accomplishing this end, in the very best, most permanent and satisfactory method, require careful study and revision of present methods.

Therefore, Be it resolved that the President of the Society appoint a committee of five (5) members to consider a revision of the present methods of conducting the Sections and to further increase the efficiency of Society work, and to prepare revised By-Laws for the Society and for the Sections, that will consolidate the management of the proceedings of Sections and the Society under one management, and that they report later such recommendations and revisions as they think best, to the Society for consideration."

This resolution was seconded by H. W. Fisher, and unanimously passed.

Announcement was made of the opening of a class to study the international language, Esperanto, in the Society rooms by H. W. Fisher.

No further business coming before the meeting the paper of the evening on the "Possibilities of the Commercial Automobile," was read by Walter W. Macfarren. The ensuing discussion was participated in by Messrs. Wilkins, J. A. Smith, Blum, Morgan, Davis, McAteer, Fisher, Prichard, Kintner and Macfarren.

The meeting adjourned at 10:45 P. M.

Elmer K. Hiles,
Secretary.

STRUCTURAL SECTION

The regular bi-monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Tuesday, September 7, 1909, at 8:20 P. M., Chairman J. A. McEwen presiding, 74 members and visitors being present.

The minutes of the last meeting, May 4, were read and approved.

The Chairman called the attention of the Section to the resolution published in the June Proceedings, presented by the Publication Committee and adopted by the Board of Direction which limits the subjects for Section meetings to Topical Discussions. The Chairman also stated that after a conference of the Executive Committee of the two Sections it had been thought necessary to file an appeal which was read.

Announcement was made that the paper on "The Foundations of the Beaver Bridge," by A. R. Raymer, previously announced for this meeting, would not be read at this time owing to the author's absence from the city and that a discussion on "Contracts With Special Relation to Structural Steel Work," had been arranged for this evening.

No further business coming before the Section the program of the evening was presented by the following speakers: Messrs. J. A. McEwen, Watson B. Adair, H. M. Stilley,

Samuel A. Schreiner, O. M. Topp, V. R. Covell, L. J. Affelder and Edward Godfrey.

The general discussion was participated in by Messrs. Albree, Gerber, Duff, Knight and Whited.

A vote of thanks was extended to the non-members of the Society for the able papers presented.

The meeting adjourned at 10:30 P. M.

ELMER K. HILES, Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday, September 14, 1909, at 7:50 P. M., President Geo. T. Barnsley presiding, Messrs. Morse, Riddle, Kintner, Grace, Handy, Chester and the Secretary being present; as was also Richard Hirsch, Chairman of the Mechanical Section.

The minutes of meetings held June 4 and August 3 were read and approved.

The Committee on Code governing the practice of engineering in the State of Pennsylvania was announced by President Barnsley in the following letter:

To the Board of Direction,

Engineers' Society of Western Pennsylvania,

Gentlemen:

Following your action at a special meeting held August 3, 1909, 'That the President appoint a committee of five members of the Society, including himself as Chairman, to co-operate with the Engineers' Society of Pennsylvania in the matter of drawing up a code governing the practice of engineering in the State of Pennsylvania, etc.' I beg to advise the appointment of the following:

Thomas H. Johnson, W. G. Wilkins.

Alternate and consulting members:

Charles F. Scott, James K. Lyons.

Yours very truly,

GEO. T. BARNSLEY, President.

The applications of the following gentlemen were received and their names ordered published to the Society:

Active

Henry Donald Fisher,	Randolph N. Randlett,
Edwin LeRoy Gemmell,	Frederick Percival Quantz,
George William Nichols,	Ray Stevens Quick.

Junior

James R. McI. Martin.

The requests of Thos. H. McGraw, Jr., who joined the Society in May, 1906, and resigned January, 1908; and George R. Harlow, who joined the Society in April, 1881, and resigned September, 1908, were received and their names ordered placed on the Society rolls.

The reports of the Secretary showing the financial condition of the Society at the close of business July 31, and August 31, having been audited by the Finance Committee were approved and bills ordered paid.

The Secretary presented the matter of raising the quality of the Society pins and authority was requested to purchase pins of solid gold which was granted; and this is made the standard Society Pin.

A communication from the Chairman of the Sections, re limitation of programs in the Sections was read and after discussion it was ordered, in view of the fact that the Publication Committee in recommending such limitation to the Board, and the Board of Direction in approving same were unaware that the By-Laws do not place the programs of the Sections in charge of the Publication Committee, that the approval of the Board of Direction be withdrawn and that the Secretary advise the Chairman of the Sections to this effect at once.

The meeting adjourned at 10:20 P. M.

Elmer K. Hiles,
Secretary.

MEMOIR

A. KENNEDY ASHWORTH.

Covington, Ky., May 26, 1873.
Crafton, Pa., January 20, 1909.

He was educated in the public schools of Pittsburgh, was a graduate in Mechanical Engineering of Rose Polytechnic Institute and studied at the Western University of Pennsylvania.

His first work was as mechanical engineer for the Joseph Horne Company, becoming chief engineer of their power plants. Two years later he became a member of the firm of D. Ashworth and Son, consulting engineers. Becoming interested in the development of engineering specialties, he associated himself with the Pittsburgh Gage and Supply Co., and established offices for this company in Chicago, New York, Philadelphia and other large cities. About eighteen months ago he returned to the main offices of his company at Pittsburgh, making his home in Crafton. At one time, earlier in his work, he was associated with the Buckeye Engine Co., and opened an office for them in Boston.

He is survived by his wife, Helen West Ashworth, his father, Daniel Ashworth, his mother Sarah Rosewell Ashworth, and two brothers, William and George Ashworth.

MEMOIR

CHARLES SEYMOUR PARSONS.

Akron, O., February 4, 1882.
Pittsburgh, Pa., May 18, 1909.

He was educated in Yale University, graduating in 1903, since which time he has lived in the Pittsburgh district. He had been employed in various capacities by the Colonial Steel Co., the Riter-Conley Mfg. Co. and the A. Garrison Foundry Co. He left the latter company to become instructor in mathematics in the night school of the Carnegie Technical Schools which position he held until appointed assistant registrar for the schools in 1907. A year later he resigned to take up work with the Pittsburgh Manufacturing Co.

He lost his life through the sinking of his motor boat while on a pleasure trip on the Allegheny River.

He was a son of William C. Parsons of New Hartford, Conn.; a brother of Robert Parsons of Akron, O., and a nephew of Prof. M. P. Seymour, Professor of Greek in Yale University.

He was a member of the Church of the Ascension, a member of its choir and a teacher in its Sunday School.

AN INTERESTING RELIC.

A very interesting relic has been presented to the Society by Mr. G. H. Danforth, accompanied by the following letter, and placed in the Club Room of the Society rooms:

Engineers' Society of Western Pennsylvania,
Mr. S. A. Taylor, Chairman of House Committee,
803 Fulton Building, Pittsburgh, Pa.

Gentlemen:—

I have delivered to-day to the Society, at the instance of Mr. E. K. Hiles, a bolt that is an interesting example of early iron manufacture in the United States, as well as an interesting relic historically. This bolt I procured from the Virginia State Capitol Building, Richmond, Va., in December, 1904, when the building was rebuilt; the bolt having been used to fasten together some large yellow pine timbers that supported the roof. This building was designed by Thomas Jefferson in 1785 and was built during the years 1785 to 1789, inclusive, and in addition to serving as a State Capitol, it also served as the Capitol for the Confederacy in 1861 to 1865. The workmanship on the bolt would not be called good at the present time, as it is evidently made entirely by hand work; the threading of the bolt, as would be evidenced by the slight twist perceptible, was probably done with the old-fashioned jam plates, such as are occasionally found in country blacksmith shops even at the present time, and both nut and washers were evidently perforated while hot with a pointed tool and not punched; the holes being tapered in both cases.

I trust this will be found acceptable to the Society. For the mounting of this specimen I am indebted to Mr. R. A. McKean.

Yours truly,

G. H. Danforth.

REGULAR MONTHLY MEETING

The 297th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Chamber of Commerce, Pittsburgh, Tuesday, October 19, 1909, at 8:20 P. M., President Barnsley presiding, 100 members and visitors being present.

The minutes of the last meeting, September 21, were read and approved.

The Board of Direction reported the receipt of six applications for Active membership; one for Junior, and one application for restoration to membership.

The appointment of the following committees was reported:

Medal Committee for 1909

F. Z. Schellenberg, Chairman

J. N. Chester — S. P. Grace

Committee on Revision of By-Laws, pursuant to action of the Society on September 21

C. B. Albree, Chairman

W. A. Bole — G. S. Davison

H. W.. Fisher — W. G. Wilkins

No further business coming before the meeting the discussion for the evening on "Rapid Transit for Pittsburgh," was opened by Dr. John A. Brashear. Messrs. L. C. Moore, H. W. Fisher, D. P. Black, F. I. Gosser, G. S. Davison, W. G. Wilkins, Morris Knowles, N. W. Storer, H. S. Anderson, C. B. Albree, R. C. Wood, also participating in the discussion.

The meeting adjourned at 10:40 P. M.

ELMER K. HILES,
Secretary.

MECHANICAL SECTION

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Tuesday, October 5, 1909, at 8:15 P. M., Chairman Richard Hirsch presiding, 48 members and visitors being present.

The minutes of the last meeting, held June 1, were read and approved.

No further business coming before this Section, the paper of the evening on "A New Type of Water Tube Boilers" was presented by Thomas H. McGraw, Jr. The paper was illustrated by lantern slides, and the ensuing discussion was participated in by Messrs. L. C. Moore, J. W. Todd, W. W. Macfarren, and Thomas H. McGraw, Jr.

The meeting adjourned at 9:30 P. M.

Elmer K. Hiles,
Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburgh, Friday, October 8, 1909, at 8:00 P .M., President Barnsley presiding, Messrs. Morse, Chester, Frost, Handy, Schellenberg, Riddle and the Secretary being present.

The minutes of the meeting held September 14 were read and approved.

The applications of the following gentlemen, having been regularly published to the Society pursuant to the action of the Board 14 September, were duly elected to membership:

Active

Henry D. Fisher	Edwin L. Gemmill
George W. Nichols	Randolph N. Randlett
Frederick P. Quantz	Ray S. Quick

Junior

James R. McI. Martin

The applications of the following gentlemen were received and their names ordered published to the Society:

Active

John S. Fielding

Junior

Thomas H. Carlin, III Walter E. Close

The request for restoration to membership of George K. Smith, who joined the Society September, 1901, and resigned March, 1904, was received and his name ordered placed on the Society rolls.

The report of the Secretary, showing the financial condition of the Society at the close of business 30 September, having been audited by the Finance Committee, was approved and bills ordered paid.

President Barnsley made the following announcement of Committees:

Medal Committee for 1909

F. Z. Schellenberg, Chairman

J. N. Chester S. P. Grace

Committee on Revision of By-Laws, pursuant to action of the Society on 21 September:

C. B. Albree, Chairman

Wm. A. Bole George S. Davison
H. W. Fisher W. G. Wilkins

President reported a request from Dr. Holmes, Director of the Technological Bureau of the United States Geological Survey, for the assistance of the President and Secretary of the Society, in going over bids received for housing the 10 000 000 lb. testing machine to be installed at the Pittsburgh Testing Station at Arsenal Park. President Barnsley further reported that as expert advice was needed on points covering certain structural features, he appointed a committee consisting of Messrs. E. K. Morse, Emil Swensson and J. K. Lyons, to assist Dr. Holmes in the matter. The contract was finally awarded to the McClintic-Marshall Construction Co.

A special meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Monday, 25 October, 1909, at 10:15 A. M., in response to the call of President Morse, to arrange details in connection with Mr. Barnsley's funeral services, to be held Tuesday afternoon, 26 October; President Morse presiding, Messrs. Riddle, Craver, Grace, Chester, Taylor, Handy, Lyons, Schellenberg and the Secretary being present.

President Morse announced that, owing to the limited time, arrangements had been made by Messrs. Davison, Swensson and himself regarding flowers, and also announced the arrangements made for the Society to attend the services in a body, notices of which the Secretary had inserted in the daily papers. Further announcement was made that the active pall bearers were to be selected from Mr. Barnsley's office and that the following honorary pall bearers had been selected:

I. K. Campbell	E. K. Morse
G. S. Davison	J. W. Patterson
D. M. Howe	Emil Swensson
J. K. Lyons	W. G. Wilkins

The arrangements made by Mr. Morse were approved.

Mr. James K. Lyons and the Secretary were requested to accompany Mr. Barnsley's famly to Washington, D. C., and to represent the Society at the interment on Wednesday.

The President was requested to appoint a Committee to draft suitable resolutions to be presented to the Board at its next meeting, which are to be spread on the minutes and copies forwarded to the family and to technical societies and press in the United States and abroad.

The House Committee and Secretary were authorized to provide suitable emblems of mourning for the Society rooms.

The meeting adjourned at 10:50 A. M.

Elmer K. Hiles,
Secretary.

REGULAR MONTHLY MEETING.

The 298th regular monthly meeting of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Fulton Building, Pittsburg, Tuesday, 16 November, 1909, at 8:15 p. m., President Morse presiding, 55 members and visitors being present.

The minutes of the last meeting, 19 October, were read and approved.

President Morse addressed the Society as follows:

In assuming the position of temporary President of the Engineers' Society of Western Pennsylvania this evening, it brings to my mind more forcibly than at any time previously the great loss that we have sustained in the sudden death of President Barnsley. There has, perhaps, been no one in recent years who has been as active as Mr. Barnsley, both as Director and President of the Society, or who has done more for the upbuilding, or had the best interests of the Society closer to heart than he.

His loss will be more and more felt in the future, and the great grief in the sudden taking away of so valuable a member is genuine and heartfelt.

Mr. Hiles and I have made a diligent search for a possible outline or rough draft of what would have been the President's address at the annual meeting, hoping that in the finding of same we might carry out his last wishes and thereby complete his year's work but as yet we have not been successful.

The Board of Direction reported the election of one Active member and two Juniors; and the receipt of five applications for Active membership and one Junior, which were ordered published to the Society.

The following report of the Nominating Committee was presented by Edward B. Taylor, Chairman, and the recom-

mendations for officers for the ensuing year were approved as follows:

President, President, E. K. Morse,
Vice-President, J. O. Handy, (2 years),
Treasurer, A. E. Frost,
Directors, A. R. Raymer and Willis Whited.

No further business coming before the meeting, the paper for the evening on "Deformed Bars vs. Round Rods Anchored for Reinforced Concrete," was presented by J. A. Toupet. The ensuing discussion was participated in by Messrs. Edward Godfrey, W. G. Wilkins, R. B. Woodworth, J. J. Shuman, V. R. Covell, Willis Whited, J. A. Ferguson, Prof. J. H. Smith, H. H. Rankin, J. A. Todd, J. H. Smith, J. A. Toupet.

The meeting adjourned at 10:40 P. M.

Elmer K. Hiles,
Secretary.

STRUCTURAL SECTION.

The regular bi-monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held in the Society rooms, Fulton Building, Tuesday, 2 November, 1909, at 8:15 P. M., Chairman J. A. McEwen presiding, 50 members and visitors being present.

The minutes of the last meeting, 7 September, 1909, were read and approved.

Chairman McEwen addressed the Section making mention of the great loss suffered by the Society in the death of President Barnsley.

Announcement was made that the next regular meeting of the Section to be held 4 January, 1910, will be the Annual Meeting, and that the Nominating Committee will be appointed to make report at that meeting.

No further business coming before the Section, the paper of the evening on "Gas Holders," was presented by Lewis Vincent; lantern slides being used in connection with the paper.

The ensuing discussion was participated in by Messrs. S. A. Duff, J. L. Mullin, R. B. Woodworth, T. J. Wilkerson, P. S. Whitman, J. A. McEwen, F. R. Sites, W. M. Judd, E. K. Hiles, H. H. Rankin, A. L. Hoerr, Henry Gulick, Lewis Vincent.

The meeting adjourned at 10:15 P. M.

ELMER K. HILES,
Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society rooms, Fulton Building, Pittsburg, Friday, 5 November, 1909, at 5:05 P. M.; President Morse presiding, Messrs. Riddle, Schellenberg, Craver, Lyons, Handy, Taylor and the Secretary being present.

The minutes of the meeting held 8 October, were read and approved.

The applications of the following gentlemen having been regularly published to the Society pursuant to the action of the Board on 8 October, were duly elected to membership:

Active
John Samuel Fielding.

Junior
Thomas Houston Carlin, III, Walter Elmer Close.

Applications of the following gentlemen were received and their names ordered published to the Society:

Active
George Phillips Cavalier, James Albert Gearhart,
Harry L. Kirker, D. M. Sloane,
Arthur Vall Spinosa.

Junior
Milton F. Stein.

The report of the Secretary showing the financial condition of the Society, at close of business 30 October, 1909, having previously been audited by the Finance Committee, was approved and bills ordered paid.

The Secretary was requested to send a circular letter to all members of the Society, giving opportunity for personal contributions to the fund provided for flowers sent as an expression of sympathy to the family of our late President, Mr. George T. Barnsley, incorporating a request that contributions of not more than $1.00 each be made.

The following report of the Nominating Committee was presented and approved:

"To the Board of Direction,

Gentlemen:

The Nominating Committee, consisting of Messrs. Walther Riddle, H. H. McClintic, G. H. Barbour, H. M. Howe and myself, appointed by the Society under Article 5 of the By-Laws, would respectfully report that they have selected for the offices to be filled candidates, as follows:

President,	E. K. Morse,
Vice-President	J. O. Handy (2 years),
Treasurer,	A. E. Frost,
Directors,	A. R. Raymer and Willis Whited.

For the committee,
EDW. B. TAYLOR, Chairman."

The meeting adjourned at 6:20 P. M.

ELMER K. HILES,
Secretary.

REGULAR MONTHLY MEETING

The 299th regular monthly meeting of December 21, 1909 was adjourned, the speaker not being present.

ELMER K. HILES,
Secretary.

MECHANICAL SECTION

The regular monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania, was held in the Society Rooms, Fulton Building, Pittsburgh, Tuesday, December 7th, 1909, at 8:20 P. M., Chairman Richard Hirsch presiding, 51 members and visitors being present.

The minutes of the last meeting held October 5 were read and approved.

Chairmain Hirsch announced the death of William Metcalf, and said:

"It is a painful duty to announce the death of the first President of the Society, Mr. William Metcalf, a man whom you all knew by reputation at least, and possibly many were intimately acquainted with him. While it is not the intention to take any formal action at this meeting of the Mechanical Section, as fitting action will be taken by the Board of Direction and by the General Society; yet, if there are any who would like to make remarks at this time, we would be pleased to hear from them. Mr. Metcalf was not only the first President but read the first paper presented before the Society, the subject being, "Why Does Steel Harden?"

Mr. Chester B. Albree made the following remarks: "I would like to say just a word. Just a week ago Saturday I sat down with Mr. Metcalf at the Duquesne Club for half an hour, presenting to him a problem that had been given to me by a firm in Washington, which had a large government contract for a lot of boats down the river. The plates were to be of

wrought iron and the man who had the contract had had the plates passed by the U. S. Inspectors, but when they began bending the plates to the different shapes required for the hull, they failed: cracking, and giving a good deal of trouble. Although the government had officially accepted the material, they rejected the boats, and this firm was trying to get evidence from men in Pittsburgh that the specifications for wrought iron were too severe and something that could not be expected of wrought iron. Not being an iron manufacturer, it occurred to me that it would be a good idea to talk with Mr. Metcalf, who was quite an authority on metallurgical subjects. I gave him the specifications which were that test bars should pull 40 000 to 50 000 lb., and bend around a diameter equal to the thickness of the plate, without fracture. He looked over the specifications and said, "That is perfectly reasonable, but you cannot get it nowadays. Wrought iron is now made partially of pig and the rest of scrap and they cannot get wrought scrap clear; if the scrap has some steel in it, it does not unite at the temperature that the pig unites and you cannot get a uniform material. The trouble is that a man cannot live up to the specifications and use any scrap now obtainable." For a man 71 years of age I think that is remarkable. Last Saturday he was just as clear in his ideas as any man I ever talked with and I think he put his finger just on the spot. I want to say this as a tribute to Mr. Metcalf's up-to-date-ness on everything that was going on."

Mr. James O. Handy made the following remarks: "When I came to Pittsburgh 20 years ago, Mr. Henry Hibbard took me to the meetings of the Engineers' Society, and Mr. Metcalf was nearly always in attendance and very generous indeed in giving the resuts of his experience in iron and steel metallurgy to the younger members. Mr. Hibbard said that he did not understand why a man like Mr. Metcalf would take the trouble to come, because he got very little from the thoughts of the younger men but gave a great deal."

No further business coming before the Section the paper of the evening, "A Gas Producer for Bituminous Fuel," was

presented by E. F. Bulmahn. Lantern slides were used and the ensuing discussion participated in by Messrs. J. K. Lyons, Richard Hirsch, J. K. Clements, J. P. Lease, O. L. Gerwig, J. A. Smitmans, H. D. Fisher, A. Stucki, H. C. Porter and E. F. Bulmahn.

Meeting adjourned at 9:35 P. M.

ELMER K. HILES,
Secretary.

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Fulton Building, Pittsburgh, Friday, 10 December, 1909, at 4:55 P. M.; President Morse presiding, Messrs. Riddle, Frost, Schellenberg, Taylor, Handy, Chester, and the Secretary being present.

The minutes of the meeting held 5 November, were read and approved.

The applications of the following gentlemen having been regularly published to the Society pursuant to the action of the Board on 5 November, were duly elected to membership:

Active

George Phillip Cavalier, Harry L. Kirker,
James Albert Gearhart, D. M. Sloane,
Arthur Vall Spinosa.

Junior

Milton F. Stein.

The applications of the following gentlemen were received and their names ordered published to the Society:

Active

Edward Jay Billings, John Dickson Stevenson.

Associate

Homer B. Melat.

Junior

Rowland Lawrence Young.

The Secretary announced the death on 5 December, of William Metcalf, a charter member and the first President of the Society. President Morse stated that he had instructed the Secretary to have suitable flowers sent to Mr. Metcalf's residence in time for the funeral services.

The Secretary read the following letter from Mr. James H. Harlow, the first Secretary of the Society:

Darlington, Md., December 8, 1909.

Mr. Elmer K. Hiles, Secretary,
Engineers' Society of Western Penna.,
Pittsburgh, Pa.

Dear Sir:

In yesterday's Philadelphia Press I note the death of my friend, William Metcalf. I have not been in touch with Mr. Metcalf since taking my present position, but I well remember when I first became acquainted with him in 1879, when we were talking about the formation of a Society of Engineers in Pittsburgh.

During the summer and fall of 1879 a few of us, William Metcalf, A. Gottilieb, James Park, Jr., N. M. McDowell, and others, discussed the forming of a Society and it was left with me to call a meeting. I asked Mr. Metcalf, "When had I better call the meeting?" and his reply was, "Call it to suit yourself and you will satisfy one at least." I have often recalled this reply as it seemed to me characteristic of the man. In other words if you have a work to do, do it, and let others fall in with you if they can. Our first meeting was held in the office of Mr. A. Dempster, then City Engineer of Pittsburgh, in December 1879.

At this meeting Mr. Metcalf was chosen temporary Chairman, and among other matters the question of name was considered. My suggestion was, "The Engineers' Club of Pittsburgh," but this was objected to by Mr. James Park, Jr., because of the word "Club." Mr. Metcalf managed the meeting so that all present were satisfied. The name chosen is the one now in use. A committee was appointed and reported a form of constitution and by-laws, and the meeting adjourned to meet in the Council room in January 1880, at which time permanent officers were chosen.

At the first meeting there were about forty present, and the Society was formed with about fifty, which was a greater number than I had expected it would have for some years.

For the first two years of the Society's life Mr. Metcalf held the Presidency, and could have held it longer but he thought one reelection was enough. I have always thought our first choice of Pres-

ident was exceptionally good and that much of the success of the Society has been due to the choice of Mr. Metcalf to direct in the formative years.

After stepping out of the Presidency, Mr. Metcalf was a directing force. I know this from personal knowledge, for as Secretary I was brought in close contact with him.

And I now note the Society is thirty years old, and may it long continue as a monument to our first President.

Respectfully yours
(Signed) James H. Harlow.

The following report of the Committee on the Columbia University Scholarship was presented, having been found among Mr. Barnsley's papers by the Secretary. This is probably the last evidence of the very faithful work which he accomplished for the Society and to which he gave so largely of his time.

October 8, 1909.

The Board of Direction, Engineers' Society of Western Penna.,
Pittsburgh, Pa.

Gentlemen:

At a regular monthly meeting held by your board on June 4th, 1909, a communication was presented from Richard B. Faulkner, M. D., President of the Alumni Association of Columbia University in Pittsburgh, inviting the Engineers' Society of Western Pennsylvania to present to the Alumni Association two nominees, one of whom to be selected as a candidate to receive a free scholarship in the Columbia University of the City of New York.

In response to this communication, you passed a resolution that a committee of five, with your president as chairman, be selected to act for the board, to respond to the invitation, with power to act.

The undersigned committee beg leave to report to you that under date of June 30th, they transmitted to all the members of the Engineers' Society, a circular letter, announcing the free scholarship offered, with blanks to be used in making application for a scholarship, embracing a full four year course beginning September, 1909.

One formal application was received within the prescribed time, namely, Mr. Anthony Wayne Caruthers, of Irwin, Pa. A final meeting of your committee was held at 7:30 P. M., August 30, 1909, for interview and final action as to the applicant. He was found to embrace

all the qualities as named in our plan of selection, and formally recommended to the Alumni Association in the following letter:

Mr. Richard B. Faulkner, M. D.,
President Alumni Association Columbia University in Pittsburgh,
Diamond Bank Building, Pittsburgh, Pa.

My Dear Mr. Faulkner:

This will introduce to you Mr. Anthony Wayne Caruthers, of Irwin, Pa., who has been selected by the committee of the Board of Directors of the Engineers' Society of Western Pennsylvania, as a candidate to accept a free scholarship in Columbia University in the City of New York.

We have had an extended personal interview with Mr. Caruthers, and we think him well up in all the requirements as outlined by us under date of June 30th, 1909, and pass him to you as a most worthy candidate to receive such a scholarship. He comes of a good family; he has passed through the Freshman year of Washington and Jefferson College, at Washington, Pa.; he has the personality and various other attributes which we think will redound to the credit of our organization. We do not anticipate that he will have any trouble in passing the entrance examinations, but think the matter should be taken up without delay, as it was our understanding that the name of the successful candidate should be filed with the Registrar of the University on or before September 5th.

It was with regret that we did not have you with us last night, and, I had also hoped Mr. Frank Schlesinger of the Allegheny Observatory, would be present, but he told me on the 'phone that it would be impossible for him to get there and he expressed the wish to see Mr. Caruthers today. I have, therefore, arranged for Mr. Caruthers to call to see you at your office, and then proceed to the Allegheny Observatory to see Mr. Schlesinger, in order that you may both pass upon the matter in hand. We take great pleasure in presenting Mr. Caruthers to you, and, at the same time transmit our very best wishes and feelings that he will be a success and credit, not only to us but to the University which he proposes to connect himself with.

Yours very sincerely,
(Signed) Geo. T. Barnsley.
Chairman, Scholarship Com., Eng. Soc. W. Pa.

It was very gratifying to your committee to receive word from the Alumni Association that, after a personal interview with our candidate, the Executive Committee of said Association, endorsed to the fullest extent, all that your committee vouched for in passing the candidate for acceptance.

Mr. Caruthers was admitted to the School of Mines in Columbia University, upon our recommendation, and the candidate is pursuing his work with entire satisfaction to all concerned. We present you a letter from the Executive Committee of the Alumni Association of Columbia University, dated October 1st, 1909, thanking our Society and expressing their appreciation for our aid and courtesy in selecting a candidate; together with other formal correspondence.

In conclusion, your committee begs to say that we believe that the action taken by our Society was in proper and direct lines for good in the educational field.

We hope that this will result in other organizations asking for advice and co-operation upon the same lines.

Respectfully submitted,
(Signed) Geo. T. Barnsley, Chairman,
E. K. Morse,
Walther Riddle.

Alumni Association of Columbia University in Pittsburgh
Richard B. Faulkner, M. D., President,
306 Diamond Bank Building.

Pittsburgh, Pa., June 3, 1909.

Engineers' Society of Western Pennsylvania.

Gentlemen:—The Scholarship of the Alumni Association of Columbia University in Pittsburgh, presented to us by Columbia University, in the City of New York, embraces a four years' course in the Columbia University School of Applied Science, leading to the degree of Engineer of Mines, Metallurgical Engineer, Civil Engineer, Sanitary Engineer, Electrical Engineer, Mechanical Engineer, Chemical Engineer, Chemist.

The usual tuition fee for the course is two hundred and fifty dollars per annum, making a total of one thousand dollars for the full four years. This Scholarship entitles the holder to *free tuition* for the four years. The Scholarship is for the term beginning September next.

We invite the Engineers' Society to present to our Alumni Association two nominees, one of whom we will select and commend to the University for the Scholarship, and the other for alternate. The particular courses will be elective by your Society.

Very respectfully yours,
(Signed) Richard B. Faulkner, M. D.,
President.

October 1, 1909.

Engineers' Society of Western Pennsylvania.

Gentlemen:—The executive committee has instructed me to thank you, and to express the appreciation of the Alumni Association of Columbia University for your aid and courtesy in selecting a candidate for the scholarship offered by the University to our Association. The candidate selected by your Society, and presented by our Association to the University, has been admitted.

Very respectfully yours,

(Signed) Richard B. Faulkner, M. D.,

President, Alumni Association of Columbia University in Pittsburgh.

The report of the Secretary showing the financial condition of the Society at close of business 30 November, having been previously audited by the Finance Committee, was approved and bills ordered paid.

The following letter, containing proposed amendments to the By-Laws of the Society, was read by the Secretary and ordered reported to the Society at its next regular meeting:

"To the Board of Direction of the

Engineers' Society of Western Pennsylvania.

Gentlemen:

Believing that the best interests of the Society will be conserved by a change in some of the existing By-Laws of the Society, the undersigned beg to submit for your consideration, and for presentation to the membership of the Society, the following amendments to the By-Laws; in each case the Sections given below to replace the corresponding Sections in the 1909 edition of the By-Laws of the Society:

ARTICLE II.

Section 10. A member of any grade in the Society *may resign* his membership by a written communication to the Board of Direction, provided he is in good standing and all dues to the Society are paid to the end of the current calendar year.

ARTICLE V.

Section 13. In case of *death* or *resignation*, of an officer of the Society, the Board of Direction shall fill the vacancy, except as provided in Section 12 of this Article. In case of the disability of, or neglect in the performance of any duty by, an officer of the Society, or absence from three successive meetings of the Board of Direction

by a member thereof, without sufficient excuse, the Board may declare the office in question vacant and fill same, except as provided in Section 12 of this Article.

ARTICLE VI.

Section 4. The following *Standing Committees* shall be appointed to serve for one (1) year; Finance, House, Publication, and Entertainment. The Chairman of each of these committees shall be chosen from among the members of the Board of Direction, and each committee shall consist of at least three (3) members, all to be appointed by the President, by and with the advice of the Board of Direction, except that the Publication Committee shall, in addition to the members so appointed, further consist of the Chairman of each Section of the Society. These committees shall report to the Board of Direction, and perform their duties under its supervision. They shall neither make expenditures nor contract any obligations for the Society, without the consent of the Board. The Chairman of each committee shall personally examine and vouch for all bills of his committee.

Section 7. The Publication Committee shall have charge of the editing and publishing of the Proceedings. It shall also have charge of the programs of the meetings of the Society and its Sections and shall have full jurisdiction with regard to all papers and topics to be presented or discussed.

(Signed) Chester B. Albree,
J. K. Lyons,
Geo. S. Davidson,
Harrison W. Craver,
W. G. Wilkins,
Samuel Diescher,
Henry W. Fisher,
Julian Kennedy,
W. A. Bole,
E. K. Morse."

In accordance with the By-Laws, action was taken on the nominees for the ensuing year. The report of the Nominating Committee being given final approval.

The meeting adjourned at 6:50 P. M.

Elmer K. Hiles,
Secretary.

EMPLOYMENT BULLETIN.

The Society has found it can do an important work as the medium for securing better positions for its members who desire them. The Secretary gives this his personal attention, and is desirous of receiving prompt notification both of positions open and of men available. Notices are not repeated except upon special request. The list of men available is made up of members of the Society, and these are on file, together with names of men not members of the Society, who are capable of filling responsible positions. Information will be sent on application.

POSITIONS OPEN

021 Wanted: Superintendent for works, manufacturing special mill and general machinery. A man able to handle the designing and construction of machinery.

022 Wanted: Draughtsman on Smelter Work. Must be experienced on structural work. This position is in Mexico, will last six months at least, pays $150.00 per month in gold and transportation both ways will be furnished.

023 Wanted: Capable man to take charge of drawing room; experienced in structural concrete design. Correspondence solicited from high grade men only.

024 Draftsman wanted experienced on furnace and structural work.

025 Draftsman wanted on Sewer and Street work. Must live in Pittsburgh.

MEN AVAILABLE

26 Engineer with several years experience as Master Mechanic for mining companies desires change. Experienced in installation work and operation. Technical education.

30 Member desires position as factory manager or mechanical engineer with concern manufacturing light or medium weight work; long experience, best references.

32 Technical graduate with 8 years experience in rolling mill and furnace work, desires to make a change. Will furnish reference and detail of experience.

33 Electrical engineer, recent technical graduate, desires position about February 1, 1910. Has had some experience in railroad work, location, maintenance and bridges, also in power plant work. Thoroughly conversant with Spanish and reads French and Italian easily.

34 Position wanted by a practical man as superintendent of Blast Furnaces, or Rolling Mill. Technical education. Highest references.

35 Position wanted by young engineer with three years' experi-

ence in steam engineering. Technical education. Experiencd in ing engines, boilers, pumps, etc.

36 Position wanted by a practical man as superintendent of Blast Furnaces or Rolling Mill. Technical education. Highest references.

37 Position wanted by engineer experienced on Rolling Mill, Furnace and general mechanical work.

38 Position wanted by structural engineer. Capable of taking charge of drafting room and pushing work through. Experienced on bridge and general structural work. Technical education.

39 Position wanted by engineer experienced in Steam and Hydraulic Engineering. Capable of filling an executive position. Technical education.

40 Position wanted by young engineer experienced on construction work about steel works. Prefer position with concrete construction company.

41 Modern foundryman desires position. Good executive, capable organizer, long and varied experience, persistent hustler, good habits. References.

42 Position wanted by young engineer experienced on field work and drafting. Have filled positions in steel works.

DISCUSSION OF PAPERS

Members of the Society and also other readers of the Proceedings are urged to send to the Secretary written discussion of papers after publication, which will be printed in succeeding issues of the Proceedings. We believe that much valuable information may be presented in this way, and it is hoped that this feature of written discussion may be made a prominent one in the Proceedings.